FINAL REPORT

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PES Project 397

USE OF FUEL OIL BY STATIONARY SOURCES IN CALIFORNIA

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ABSTRACT

This study was performed to obtain an accurate account of fuel oil consumption in California for stationary sources in the calendar year 1977. Methodology development emphasized the most direct approach to secure necessary fuel oil usage patterns. Information was collected from sources in the industrial, commercial and institutional sectors through a questionnaire survey of potential users. On the other hand, methodology development for the agricultural and residential sectors involved a less direct approach in which local/county specific secondary data were used.

Information requirements for the overall approach necessitated a level of detail to report data by combustion equipment within each county of the state, along with various usage patterns such as temporal and spatial resolution. For spatial resolution the methodology also considered acquiring the necessary land use patterns to grid the Los Angeles, San Diego, and San Francisco Air Basins. Finally, the methodology considered the development of various fuel oil characteristics.

The final report presents the considerations taken into account in developing the methodologies, procedural steps, and summarized totals. A computer magnetic tape file containing all information collected on the individual facilities surveyed and all gridded information was also delivered to the ARB.

ACKNOWLEDGMENTS

The successful completion of this study depended upon the cooperation of many individuals and groups, especially personnel of the California Air Resources Board and the various air pollution control agencies in California. Numerous other governmental agencies and trade association groups provided invaluable time and expertise to the study. Though forebearing to list all organizations due to the excessive length of the roll, the authors wish to take this time to express our appreciation to all who contributed to the successful completion of this study. The following individuals played key roles in the study.

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1.0 INTRODUCTION

1.1 BACKGROUND AND SCOPE

In its role as a regulatory agency, the California Air Resources Board (ARB) must be able to estimate the burden exerted on California air quality by the myriad of pollution-causing sources. A crucial phase of this effort is the accurate compiling of emission inventories at least to the level of detail for the development of adequate control strategies. It is thus not surprising that the quantification of fuel oils by stationary combustion sources is an integral part of these inventories.

The primary effort of the ARB has been directed towards the major point sources, where identification is relatively easy with the aid of agency permit and enforcement records. For small point sources and essentially all area sources, the quality of information ranges from good to poor; in some instances the information is nonexistent. This situation is magnified in the area of non-power plant stationary source fuel oil combustion. To illustrate, in a few of the state's smaller counties where fuel oils are known to be consumed, no information is available at either the state or local level.

Notwithstanding mobile source fuels, the primary emphasis of energy consumption research in the state has historically focused on electricity and natural gas usage. Consequently, there is a wide spectrum of detailed information available (i.e., end user, temporal, and so forth) at all geographical levels for these two energy sources. This is due, in part, to the fact that these are the state's two primary sources of energy. Conversely, end user specific information on non-power plant consumption of fuel oils is relatively unavailable at all levels. Most of the work effort in compiling data on fuel oils has been predicated on the Department of Energy's (DOE) annual statewide estimates. The accuracy of these data are suspect due, in part, to the rough mass balance techniques used in developing the totals on the national/state level.

Thus, the ARB sponsored this study for the primary purpose of closing these data gaps by compiling a comprehensive stationary combustion source fuel oils inventory for the year 1977. Utility power plants were the only end user excluded since the ARB tracks these sources through other reporting mechanisms. In summary, the three main objectives of this study were to:

- Compile an accurate annual fuel oils combustion inventory for non-power plant stationary sources in each county of the state.
- Develop monthly consumption profiles by county, by fuel oil type, and by end user.
- Resolve the inventories for the counties in the state's three major metropolitan air basins [i.e., San Diego, Los Angeles (South Coast), and San Francisco (Bay Area)] on grid systems of 10 km by 10 km grid cells.

1.2 APPROACH AND RATIONALE

In general, the approach taken to achieve the above objectives involved (1) a qualitative review of the subject area, (2) the distilling of the acquired knowledge to plausible methodologies, and (3) the execution of those methodologies.

The initial activity involved contacting a number of energy-related organizations (e.g., California Energy Commission, U.S. Department of Energy, and others) to determine the availability of data. These inquiries revealed that much of the detailed end user data required for a study of this scope were, for the most part, nonexistent. It should be noted, however, that many of these organizations have attempted to compile accurate fuel oil consumption profiles for the state. Unfortunately, these efforts have either been unsuccessful or have yielded dubious results.

A case in point was the State Board of Equalization, Statistical Research Unit's effort several years ago to develop a statewide fuel oil consumption profile. The study was based on the premise that fuel oil usage can be linked to fuel taxes. Although this appeared to be a reasonable argument, the Unit was faced with the fact that fuels are not subject to "usage type" taxes. Moreover, since taxes paid by fuel oil suppliers do not differentiate commodities, end user information is also not available from the tax base.

Because of these problems, the Statistical Research Unit attempted to solicit assistance from the fuel oil suppliers to provide them with the mechanism to fractionate the tax records by product type. The suppliers refused this request based on issues of confidentiality. Thus, the Unit then initiated a program to collect this data from the suppliers by guaranteeing anonymity. This procedure also failed to receive supplier cooperation. Therefore, since the Unit did not have the necessary legal authority to enforce such requests, and since cooperation from the suppliers was not forthcoming, the issue was set aside.

One final comment on the available fuel oil data needs to be made. Nearly all of the fuel oil data bases compiled heretofor are, for the most part, based on sales data. The critical problem is that fuel sales data for a given area do not necessarily represent the fuel consumption rate for that area. Cutback asphalt is a classic example of this phenomenon. It is not unusual to find a refinery producing, among other materials, cutback asphalt in an area (e.g., a particular county) where it is not used for any given number of reasons. But sales records would imply its usage in that area. Consequently, sales data must be used with reservation when the intent is to generate end user profiles.

It was thus evident that since accurate or reliable end user data were unavailable, a technical approach needed to be constructed to meet the project objectives while recognizing the priorities of the internal inquiries. Accordingly, the methodology development focused on inventory techniques that allow for the most direct approach possible within project constraints. To this end, for instance, all potential fuel oil users identified in the industrial, commercial, and institutional sectors were queried via a mailout questionnaire survey. Development of a mailing list for these sources centered around information contained in air pollution control agency files augmented with information collected from many state and local governments and trade associations.

For the residential and agricultural sectors, where a survey of end users is neither prudent nor economically beneficial because of their inaccessibility and vast number, a less direct approach was required. All county air pollution control districts (APCD) with the exception of two (Santa Barbara and Yolo-Solano APCDs declined to participate in this study) were questioned with regard to these sectors. Also, numerous state and local governments and end user associations were contacted for local/county specific data. From these discussions and subsequent data collected, specific algorithms were developed and executed for these sectors.

Lastly, local planning organizations were contacted to acquire necessary land use data for the three gridded air basins. Industrial, commercial and institutional establishments were gridded based on the spatial information provided on questionnaires while the land use maps were used to grid residential and agricultural data.

1.3 SUMMARY AND CONCLUSIONS

Table 1-1 summarizes the county consumption estimates of total fuel oil that were generated by end user sector during this study. It comes as no surprise that the industrial, commercial, and institutional sectors comprise the majority of the county totals.

Table 1-1. TOTAL FUEL OIL CONSUMPTION BY SECTOR BY COUNTY, 1977

COUNTY	AGRICULTURAL	RESIDENTIAL	INDUSTRIAL/ COMMERCIAL/ INSTITUTIONAL	COUNTY TOTALS
Alameda	40	0	8,090	8,130
Alpine	0	40	0	40
Amador	30	270	0	300
Butte	340	480	1,840	2,660
Calaveras	20	120	142	282
Colusa	220	60	0	280
Contra Costa	190	0	41,600	41,800
Del Norte	30	420	491	941
El Dorado	80	920	222	1,220
Fresno	6,640	1,090	11,500	19,230
Glenn	210	140	1,430	1,780
Humboldt	80	830	10,900	11,800
Imperial	190	0	22,800	23,000
Inyo	70	220	3,800	4,090
Kern	4,300	0	83,900	88,200
Kings	2,260	90	2,920	5,270
Lake	1,750	530	119	2,400
Lassen	70	1,200	1,710	2,990
Los Angeles	340	0	73,300	73,600
Madera	1,140	60	1,200	2,400
Marin	3	0	0	3
Mariposa	Neg.	170	0	170
Mendocino	940	1,610	9,340	11,900
Merced	1,540	220	1,920	3,680
Modoc	160	790	52	942
Mono	70	290	0	360
Monterey	480	0	15,900	16,400
Napa	780	0	57	837
Nevada	10	2,250	403	2,660
Orange	260	0	5,970	6,230
Placer	90	1,180	106	1,380
Plumas	30	1,010	923	1,960
Riverside	3,240	0	10,400	13,600
Sacramento	210	0	4,800	5,010
San Benito	80	0	233	313
San Bernardino	2,400	0	82,500	84,900
San Diego	790	0	7,130	7,920
San Francisco	0	0	203	203
San Joaquin	640	370	16,200	17,200
San Luis Obispo	310	0	1,260	1,570
San Mateo	10	0	355	365
Santa Barbara	210	0	5,330	5,540
Santa Clara	110	0	372	482
Santa Cruz	80	0	11,900	11,200
Shasta	50	900	1,200	1,340
Sierra	30	330	0	360
Siskiyou	610	2,110	599	3,320
Solano	220	0	2,200	2,420
Sonoma	140	0	1,100	1,240
Stanislaus	1,340	290	7,720	9,350
Sutter	250	0	89	339
Tehama	120	360	0	480
Trinity	2	160	14	174
Tulare	4,520	380	2,990	7,890
Tuolumne	10	120	2,150	2,280
Ventura	400	0	4,180	4,580
Yolo	100	0	1,680	1,780
Yuba	110	180	576	866
STATE TOTALS	38,300	19,200	466,000	524,000

[a]Expressed in thousands of gallons.

In fact, these sectors account for more than 88 percent of the non-power plant fuel oil consumed in the state. Moreover, the largest end user category is the industrial sector which has a consumption rate of more than 75 percent of this study's totals. If power plant usage were included in these estimates, then the industrial sector's proportion would be more than 94 percent of the statewide consumption rate (based on DOE power plant figures for 1977).

In general, the county estimates shown in Table 1-1 are possibly on the lean side of the "actual" consumption values. This conclusion is based on two observations. First, the questionnaire survey of the sources identified in the industrial, commercial, and institutional sectors was somewhat less than 100 percent successful in terms of the response rate. Secondly, there is the distinct possibility that there are a relatively minor number of small fuel oil end users that were not identified for survey. To appreciate this latter remark, it should be noted that the survey mailing list was very carefully constructed from the best available information and that the unidentified sources are believed to be isolated to the smaller consuming sectors (i.e., the commercial and institutional sectors).

Finally, the survey response rate (71 percent) should not be construed as being linearly related to the estimates. This is because a significant proportion of the work effort was aimed at acquiring information on the presumed large sources. For the most part, this effort was very successful.

In the case of the residential and agricultural sectors where secondary (nondirectly acquired) locale-specific data were incorporated into preconstructed fuel oil estimating algorithms, the estimates are considered to be of high quality in terms of the overall effort. Briefly, the estimates were generated by incorporating secondary data into area-specific algorithms.

No error estimate or sensitivity analysis was performed on the data base, as a greater level of effort would be required to establish the distribution and accuracy of all the variables in a statistical manner. Nevertheless, it is useful at this point to comment on the accuracy of this study's annual estimates. The principle problem in this assessment is the uncertainty in knowing the true values. This uncertainty may indeed never be resolved because of the exceedingly complex nature of the fuel oil distribution network. It is more appropriate, therefore, to assess the quality of the inventory in terms of completeness, the rigor of the methodologies and their execution, and whether or not the results are reasonable in light of other studies and engineering judgment.

In regard to completeness and rigor, this inventory is considered to be of high caliber based on documentation presented in the remainder of this report. The third element, that of being reasonable, is not as easily evaluated. Even though the results are quite reasonable from an engineering point of view, it would be useful to compare the results to other studies so as to complete this brief analysis.

It appears that the only reasonable data available with which to draw a comparison is the DOE statewide estimate for 1977. This estimate is based on domestic sales data rather than on estimates of fuel-fired to combustion units. Nevertheless, if it is assumed that the sales figure represents an "upper limit" estimate of fuel-fired at an undetermined error, then a coarse comparison can be made. Thus, employing engineering judgment at the lower limit along with the DOE figure, it is estimated with qualification that the inventory is within 5 to 60 percent of the true value. Based on this admittedly crude analysis, it is felt that the inventory's technical approach strikes a balance between maximum potential accuracy and the rapidly increasing level-of-effort required as estimates become incrementally more precise.

Finally, Figure 1-1 illustrates the monthly temporal distribution of the total fuel oil consumed in each sector at the state level. Since the majority of the total fuel oil is accounted for by the industrial, commercial, and institutional sectors, the composite graph most closely represents these sectors.

Some general remarks concerning the inventory as a whole are in order. First, it appears that in many ways 1977 is an atypical year both in terms of weather and consumption patterns. For instance, 1977 was one of the worst drought years on record. This calamity resulted in an abnormal rise in energy consumption for irrigation. Secondly, 1977 appears to have been the last year that facilities on a natural gas end use priority system experienced a non-negligible curtailment of their primary fuel. Since most of these point source facilities use fuel oil as standby, the 1977 figures on a plant-by-plant basis may be elevated when compared to more recent years.

The conclusion to be drawn from the last paragraph is that caution must be exercised before using the information herein as a forecasting base line. Further discussion of this issue is provided in the remainder of this report.

Table 1-2 indicates the estimated distribution of the state's fuel oil total by type and by sector. The pattern for the industrial, commercial and institutional sectors is "hard" data in that it was determined through direct contact of end users. The two area source sectors, on the other hand, represent PES appraisal stemming from the knowledge gained during the course of this study. In reality, however, the fuel oil consumed in these two sectors may better be classified as simply middle distillates.

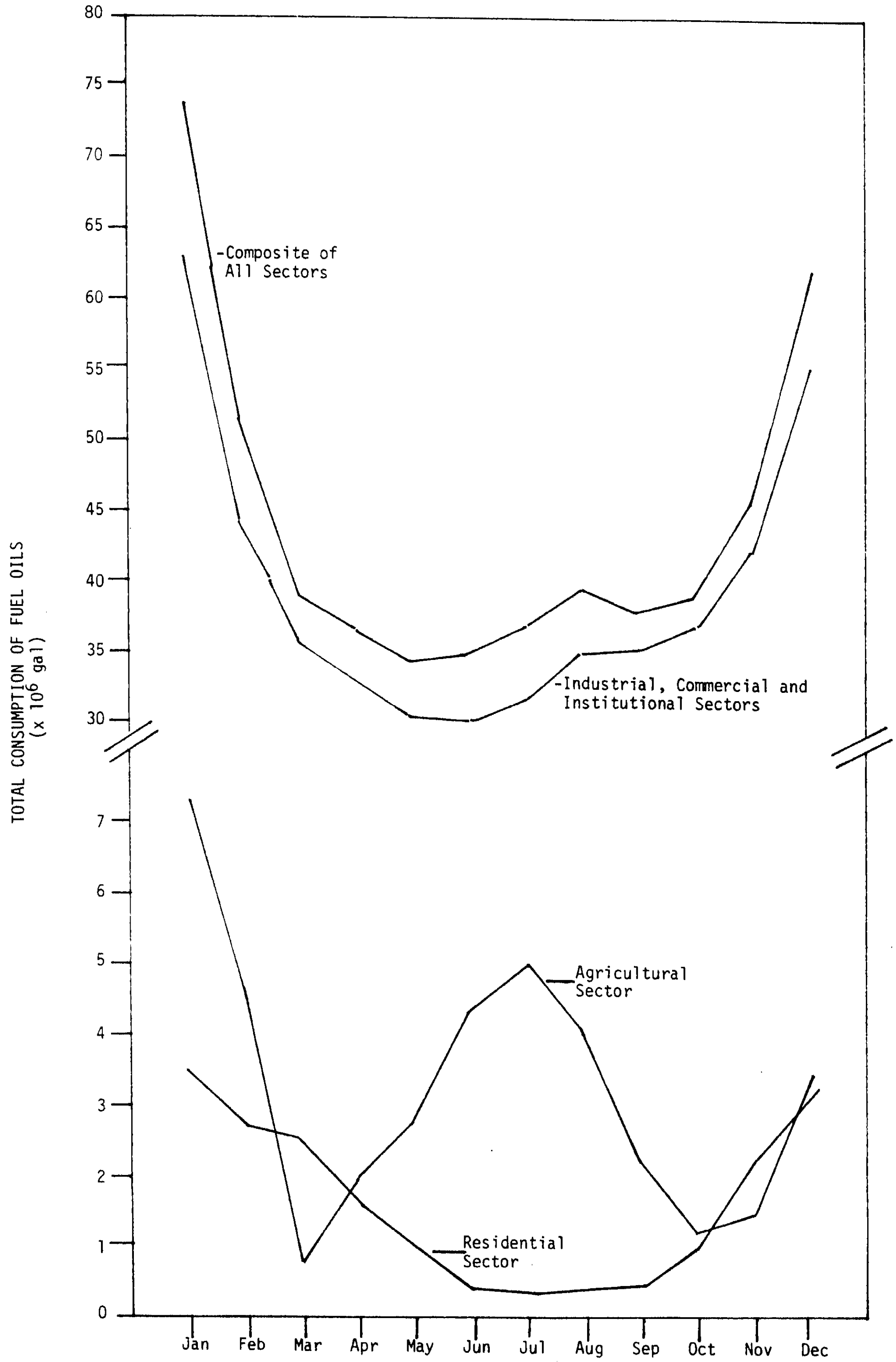

Figure 1-1. Monthly Consumption of Fuel Oils in California, Excluding Power Plants, 1977

Table 1-2. TOTAL FUEL OIL CONSUMPTION[a] BY SECTOR, BY TYPE, 1977

SECTOR	FUEL OIL TYPE				
	No. 1	No. 2	No. 4	No. 5	No. 6
Industrial, Commercial and Institutional	2.41	105	6.8	42.7	309
Agricultural		38.0			
Residential		19.0			
TOTAL	2.41	162	6.8	42.7	309

[a]Expressed in millions of gallons.

1.4 RECOMMENDATIONS

During the course of this study, several items have surfaced that, in PES' opinion, should be investigated further. These problem areas are delineated below.

- The ARB is currently using a simplified algorithm to develop fuel oil estimates for the residential sector with the purpose of generating emission estimates. An elaborate analysis was performed in this study with much the same results. The only major difference being that the ARB study allocated usage totals to counties identified in this study as having none. Therefore, it is recommended that the ARB continue to use its residential algorithm for updating purposes, but delete consumption totals for the counties identified in this study as having none.

- The ARB algorithm for frost protection and the one developed for this study provided some significant differences in county totals. First, as in the discussion above, the ARB algorithm allocated fuel usage to counties that were found in this study to have none. Secondly, some of the county totals were significantly different. Therefore, in light of the current study, the ARB should further evaluate its frost protection algorithm.

- It appears that agricultural irrigation is not currently contained in the ARB inventory. Results of this study indicated statewide fuel oil usage for irrigation to be approximately 24.2 million gallons, of which over 65 percent were consumed in the San Joaquin Valley. Because of the potential significance of this activity, especially in the area mentioned, it is recommended that the ARB should consider incorporating this category into their inventory system.

- As alluded to in Section 1.3 and as discussed further in Section 2.0, there are many factors which affect fuel oil consumption in any given year. Consequently, forecasting any given year, such as 1977, will not necessarily provide reliable results. Thus, another study should be undertaken to examine long-range trends and patterns, especially with regard to the various indicators used in the present study. An analysis of this type would allow for more reliable forecasting methods than are currently available for these sources.

- As discussed in Section 4.4.5, a problem developed in the survey portion of the study due to the initiation of a similar fuel survey by the regulatory group of ARB. This event directly affected the results of both surveys and alienated industry members who received both fuel questionnaires. It is quite evident that better coordination within the various groups of ARB would only serve to help project a more responsive attitude towards industry.

2.0 HISTORICAL ENERGY USE IN CALIFORNIA

To fully appreciate the 1977 energy use patterns in California, it is useful to briefly examine the historical trends and patterns of growth. Failure to do so creates the risk of attaching inappropriate meaning to a single year's worth of energy consumption data.

After World War II, the predominant fuel used by new households and new businesses in California was natural gas. It was an attractive source of energy since it was clean-burning and relatively inexpensive. Fuel oil, on the other hand, was used primarily as a standby energy source during this period, since a significant percentage of electric utilities used hydroelectricity or natural gas and industries preferred natural gas.[1]

Demand for energy, in general, grew rapidly in California during the early 1960's (see Figure 2-1). The decade of the 1970's, however, witnessed a slowdown in the rate of growth in energy demand and a change in the profile of the type of energy in demand.[3]

Several factors contributed to these changes. In 1972, the state experienced a decline in the availability of both California and imported natural gas. This decrease in supplies was not immediately noticed, however, as it was almost completely absorbed by the large conversions of electric utilities from natural gas to petroleum products for boiler fuel (see Figure 2-2).

While these domestic supplies of natural gas were being depleted, the Arab oil embargo occurred in late 1973. This marked the end of an era of relatively inexpensive energy in California. The higher prices for crude oil resulted in a decrease in the use of gasoline for motor fuel. During the period 1973 to 1975 this decreased utilization balanced the increased demand for fuel oils by utilities.[3] The oil embargo also resulted in a slowing in the growth rate of electricity demand. Higher prices and various

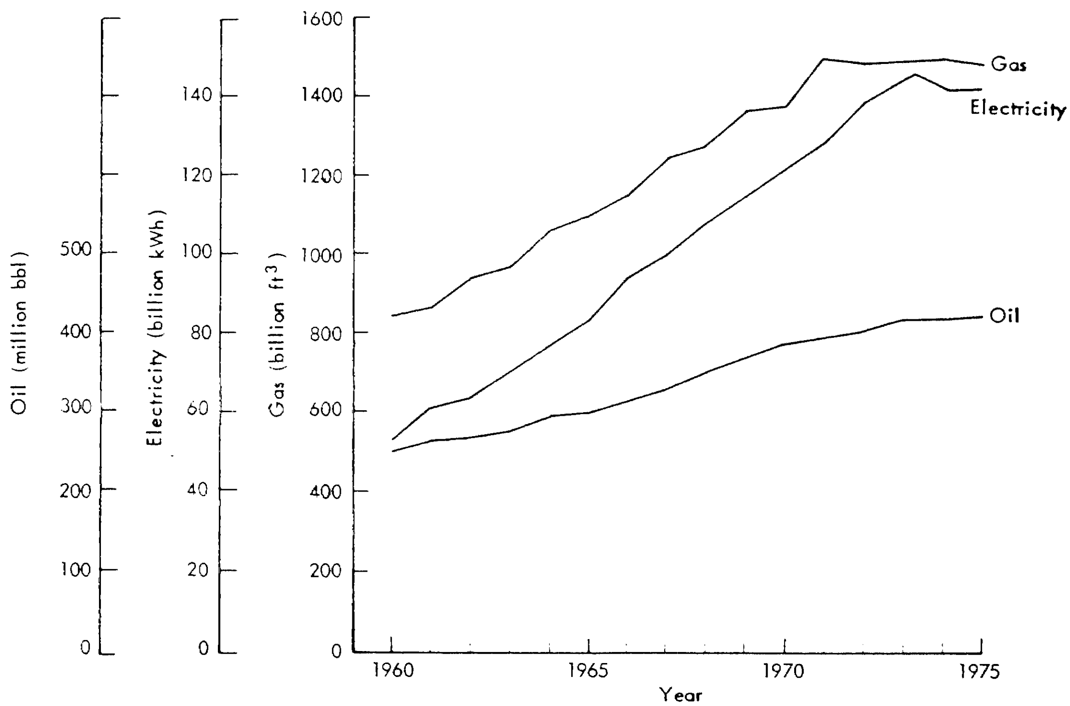

Figure 2-1. Trends in End Use of Energy in California[2]

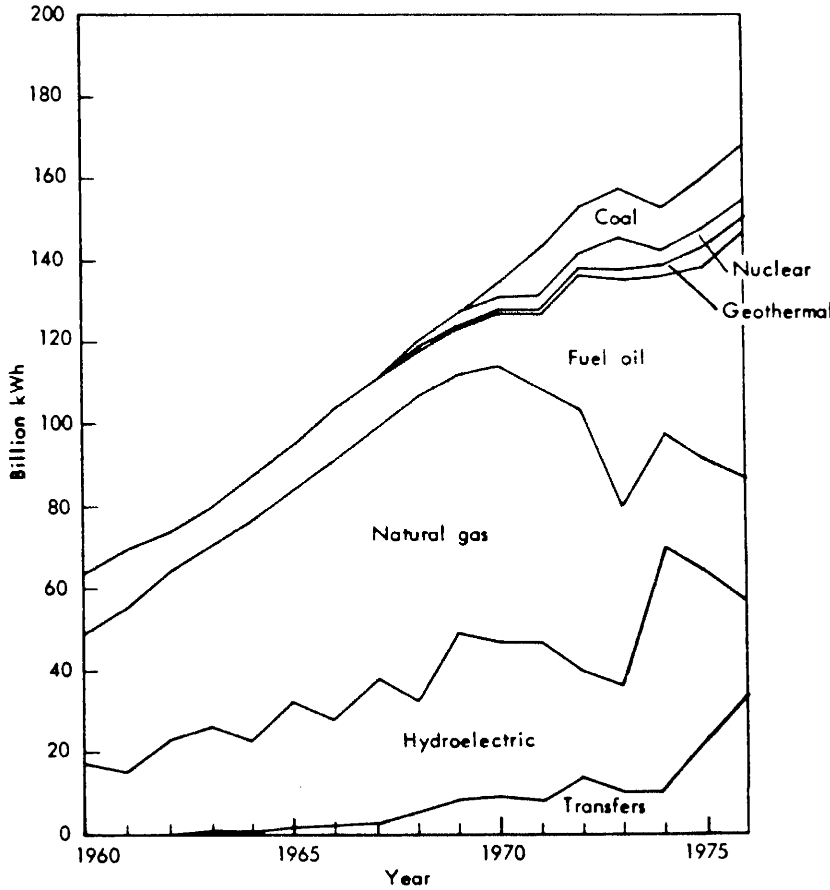

Figure 2-2. California Electricity Production by Source [4]

voluntary conservation actions on the part of both utilities and individual customers were the key factors in this post-embargo.

The shift away from historical trends and patterns of energy consumption that took place in the 1970's creates numerous difficulties for an analyst who is trying to predict energy consumption patterns for future years. In particular, it is necessary to exercise caution in interpreting short-term "trends," especially for periods that occurred during the mid-1970's. This is well illustrated by the following statistics:[3]

Time Period	Electricity Demand Growth Rate
1973-1978	1.2%
1974-1978	2.7%

In the years prior to the mid-1970's a base year shift of one year in a 4 to 5 year period would not be expected to produce a dramatic shift in energy demand growth rate. This was not the case during the mid-1970's. As the statistics given above indicate, using 1974 to 1978 as the relevant averaging period had the effect of producing a higher growth rate than would otherwise be the case (e.g., the 1973 to 1978 period). Such a growth rate would be a distortion of reality since it would be based upon a year (1974) in which the general economy was in a state of recessing and electricity sales had declined 4.7 percent from the previous year. Although not ideal, the 1973 to 1978 growth rate is a more reasonable indicator of long-term trends because it tends to smooth out the effects of the 1974 economic slowdown.

Similar logic can be applied to the base year of the present study. Just as 1974 was a year in which the economy was in a general downturn, it is possible that any other year (e.g., 1977) could reflect an anomalous state of upturn or downturn relative to the general historical trend. Likewise, just as the mid-1970's witnessed a rather dramatic change in historical trends and patterns in energy consumption, it is very possible that the period following 1977 could witness a similarly dramatic change. Indeed, such a change has been occurring since the 1979 crisis in the Middle East.

REFERENCES FOR SECTION 2.0

1. California Energy Resources Conservation and Development Commission, California Energy Trends and Choices: 1977 Biennial Report, Volume I: "Toward a California Energy Strategy: Policy Overview."

2. Ahern, William, et al., "Energy Alternatives for California: Paths to the Future." Rand Corporation, December 1975.

3. California Energy Commission, "California Energy Demand 1978-2000, A Preliminary Assessment," August 1979.

4. Stanford Research Institute, Meeting California's Energy Requirements, 1975-2000.

3.0 FUEL OIL DEFINITION

The term fuel oil applies to a wide range of petroleum liquids. In general, most products currently marketed as fuel oils are made by the fractional distillation of crude oil stocks. Desulfurization, hydrogenation, cracking, and other refinery processes are performed on some fractions to remove impurities and to establish upper and lower limits of selected physical characteristics. Blending of these fuel stocks may also occur depending on the specification requirements of the customer.

There are a variety of systems available for categorizing these refined fuels including but not limited to the Pacific Standard Numbers, the American Society for Testing and Material (ASTM) fuel oil grades, and the dated marine designation of Bunker Fuel Oils. The ASTM grading system is the most widely used by fuel oil consumers and the most descriptive in terms of classifications according to broad specifications. As such, this fuel oil grading system, which is discussed below, was adopted for this study.

The ASTM system groups fuel oils into two main branches, the distillate fuel oils and the residual fuel oils. There are two members of the distillate branch which are referred to as grades No. 1 and No. 2. The members of the residual branch are grades No. 6, straight run (refining limited to fractionation) No. 4, and No. 5. Additionally, blending of grades No. 2 and No. 6 produces grades No. 4, No. 5 light, and No. 5 heavy. Whether the lighter residuals (No. 4 and No. 5) are straight runs or blended, their ASTM characteristics are the same. There is no grade No. 3 in the ASTM scheme. Table 3-1 indicates the various specifications for the five fuel oil grades.

Table 3-1. ASTM DETAILED REQUIREMENTS FOR FUEL OILS[a]

Fuel oil grade	Description and requirements for use	Flash point, °F. (°C.)	Pour point, °F. (°C.)	Water and sediment, vol. %	Carbon residue on 10% bottoms, %	Ash, wt %	Distillation temperature, °F. (°C.) 10% point	Distillation temperature, °F. (°C.) 90% point		Saybolt viscosity, sec. Universal at 100°F. (38°C.)		Saybolt viscosity, sec. Furol at 122°F. (50°C.)		Kinematic viscosity, centistokes At 100°F. (38°C.)		Kinematic viscosity, centistokes At 122°F. (50°C.)		Gravity, °A.P.I.	Copper strip corrosion
		Min.	Max.	Max.	Max.	Max.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
No. 1	A distillate oil intended for vaporizing pot-type burners and other burners requiring this grade of fuel	100 or legal (38)	0	Trace	0.15	...	420 (215)	...	550 (288)	...	...	...	...	1.4	2.2	...	...	35	No. 3
No. 2	A distillate oil for general-purpose domestic heating for use in burners not requiring No. 1 fuel oil	100 or legal (38)	20 (−7)	0.10	0.35	...	...	540 (282)	640 (338)	(32.6)	(37.93)	...	...	2.0	3.6	...	...	30	
No. 4	Preheating not usually required for handling or burning	130 or legal (55)	20 (−7)	0.50	...	0.10	...	...	...	45	125	...	...	(5.8)	(26.4)				
No. 5 (light)	Preheating may be required depending on climate and equipment	130 or legal (55)	...	1.00	...	0.10	...	...	...	150	300	...	...	(32)	(65)				
No. 5 (heavy)	Preheating may be required for burning and, in cold climates, may be required for handling	130 or legal (55)	...	1.00	...	0.10	...	...	...	350	750	(23)	(40)	(75)	(162)	(42)	(81)		
No. 6	Preheating required for burning and handling	150 (65)	...	2.00	...	...	...	...	...	(900)	(9000)	45	300	...	...	(92)	(633)		

[a]Reference 1.

The residual grades are markedly less expensive than the distillate grades but require more elaborate burner equipment for proper combustion. Consequently, the residual grades tend to be fired in the larger units. In the case of the smaller units, particularly those that burn natural gas on curtailable leases, preference is given to use cleaner, more troublefree distillate grades as standby. To further focus the application of fuel oils, the following briefly describes where the various grades are likely to be found.

Grades No. 1 and No. 2 usually are found in the application of very small units, such as space and water heating. Grade No. 2 is also found in agricultural and industrial processes where relatively easy burning is required and the firing rate is usually not more than 20-25 gallons per hour (gph).

Of special note, there is some confusion over the use of the terms "No. 2 fuel oil", "diesel fuel" (used principally in mobile units), and "distillate fuel oil." The distinctions between these terms are rather minor. Therefore, for purposes of this study, they were all considered Grade No. 2.

No. 4 is normally used in larger commercial and industrial applications where the units are firing up to 50 gph. Grade No. 5 is found in similar situations but also in units in the 50 to 100 gph range because of its increased heat content. Finally, Grade No. 5 is found in many applications where firing rates are above 50 gph.

REFERENCES FOR SECTION 3.0

The following references were consulted in preparing this section.

1. American Society for Testing and Materials, "Standard Specifications for Fuel Oils", publication D396.

2. "Bunkie's Guide to Fuel Oil Specifications", NOFI Technical Bulletin No. 68-101, National Oil Fuel Institute, Inc., NY, NY.

3. Chemical Engineers' Handbook, 5th Ed., McGraw-Hill Book Co., Inc., NY, NY.

4. Air Pollution Engineering Manual, 2nd Ed., AP-40, U.S. Environmental Protection Agency, Research Triangle Park, N.C., May 1973.

4.0 METHODOLOGY DEVELOPMENT AND 1977 FUEL OIL ESTIMATES

4.1 OVERVIEW

Methodology development in this study emphasized the most direct approach possible to secure accurate information on fuel oil consumption by stationary sources in California, excluding power plants. Information requirements for the overall approach necessitated a level of detail to resolve the data base by stationary combustion equipment within each county of the state, along with various usage patterns such as temporal and spatial resolution. For spatial resolution the methodology also considered acquiring the necessary land use patterns to grid the Los Angeles, San Diego, and San Francisco air basins. Finally, the methodology considered the development of various fuel oil characteristics.

Various methods can be engaged to yield fuel oil consumption estimates. The most accurate and reliable approach is to contact all end users directly. This is essentially the approach that was used to assess the industrial, commerical and institutional sectors. Identification of end users in the industrial sector and large establishments in the commercial and institutional sectors was accomplished by examining current ARB and local APCD file data. Since many commercial and institutional establishments are not contained in agency files because of their relatively small size, comprehensive source lists of these sources were developed by contacting various governmental and trade associations.

On the other hand, information on smaller sources such as those found in the agricultural and residential sectors is essentially nonexistent in permit files. Moreover, a detailed mail survey of end users in these sectors is not feasible due in part to their inaccessibility and the vast number of potential sources. Therefore, methodology development for these sectors involved a less direct approach in which local/county specific secondary data (i.e., published data, interviews with trade associations, cooperatives, and so forth) were used.

Finally, to simplify data manipulation and provide the reader with a lucid view of the assessment procedures, most of the data contained in this report have been rounded to three significant figures. In some cases, it may appear that the data contained in various tables and sections do not "add up," but this supposed inaccuracy is due to the rounding process and does not affect the overall precision of the study.

4.2 RESIDENTIAL SECTOR

4.2.1 GENERAL

Energy usage in the residential sector is broadly for space heating and cooling, water heating, cooking, lighting, clothes drying, and miscellaneous minor uses, such as household appliances. As expected from common experience, the energy consumed in a household is supplied in different forms for various purposes. Tables 4-1 and 4-2 illustrate this point by considering the distribution of the various fuel types used in this sector as well as their application.

From these data, distillate oil is the only fuel oil type used in this sector. Moreover, it appears to be confined to space heating, water heating and cooking. Both of these findings were verified for California by examining the Bureau of Census housing data for this state.[2]

According to the figures for the Pacific area of the country, the usage of distillate oil for cooking could be an important consideration for California. However, from conversations with local APCDs and from reviewing various documents dealing with energy usage (e.g., References 2 and 3), the application of this fuel for cooking is not believed to occur in California to any significant

Table 4-1. PERCENTAGE DISTRIBUTION OF FUEL TYPES BY USE IN THE US RESIDENTIAL SECTOR, 1974[a]

Fuel Type	USE				
	Space Heating	Water Heating	Cooking	Other	All
Natural Gas	63	29	6	2	100
Electricity	13	23	9	55	100
Distillate Oil	77	9	14	0	100
LPG	59	27	14	0	100
Kerosene	70	5	25	0	100

[a]Data extracted from estimates for Btu consumption by fuel use in Reference 1.

Table 4-2. PERCENTAGE DISTRIBUTION OF FUEL TYPES IN THE RESIDENTIAL SECTOR, 1974[a]

Fuel Type	GEOGRAPHIC AREA	
	USA	Pacific[b]
Natural Gas	48	63
Electricity	18	24
Distillate Oil	25	8
LPG	6	4
Kerosene	3	1
Residual Oil	0	0
Other	0	0

[a]Data extracted from estimates of Btu consumption by fuel by geographic area in Reference 1.

[b]Includes Alaska, Washington, Oregon, and California.

extent. Consequently, this study will consider fuel oil usage in the residential sector to be confined to space and water heating.

4.2.2 ANNUAL ESTIMATES

Although there are several analytical techniques that can be employed to estimate fuel oil consumption rates in this sector, they can be categorized into one of two basic methodologies. In the first case, one relies on either a published or mathematical generated state consumption total which is then apportioned to the counties according to the distribution of some related demographic variable (e.g., population). In the other case, multivariable expressions requiring area-specific data are used to approximate consumption rates directly at the county level. These expressions are generally developed from multiple regression analysis.

Of special note is a technique developed by the ARB based on annual estimates of the volume of natural gas consumed by residential customers in each county of the state. This technique falls into the latter basic methodologies group even though regression analysis is not involved. In the ARB method, the natural gas consumption data are coupled with the estimated housing stock using this fuel to generate average household non-electrical energy demand in each county. These data are then combined with estimates of the distillate oil using housing stocks and an estimated fuel heat content to yield county fuel oil rates. The ARB indicates that this approach takes into account energy consumed for space heaters, water heaters, and cookery equipment.[3] As pointed out earlier, PES has dismissed the use of fuel oil for cooking in California, but does appreciate the difficulty the ARB would have in fractionating the county natural gas consumption rates.

In the first basic methodology group, fuel oil consumption rates tend to be generated for all of the counties. In other words, it presupposes that fuel oil is used in each geographic location where the allocation parameter is found (e.g., population). On the other hand, the second group determines fuel oil usage in these areas where the appropriate housing stock is found. The second general method does not, in principle, suffer from the hazard of placing fuel oil in areas where it is not actually used. However, there does tend to be a problem in appraising the magnitude of the distillate oil using housing stock at the county level.

It has been PES' experience that housing stock data in most inventory work originate from the Bureau of Census. For example, this is the source of ARB's recent work[5] as well as in the internal area source methodologies found in U.S. EPA's National Emissions Data System (NEDS).[6,7] However, PES has found that the Bureau of Census data are sometimes at odds with the local planning agencies and the local APCDs as to the fuel types actually used in their respective counties. To illustrate, the Bureau of Census data indicates fuel oil in every county in California based on housing stock which is contrary to the opinion of the APCDs. In fact, from conversations with all of the APCDs, the counties shown in Table 4-3 were indicated to have either no fuel oil usage in the residential sector or to have negligible unaccountable amounts. Consequently, for purposes of this study these counties are considered to have zero consumption rates for 1977.

In order to determine fuel oil use in the remaining counties (to be compared with the ARB results), an equation developed via a statewide regression analysis was selected.[8] The equation was originally arrived at by examining the relationship between fuel consumed for home heating and degree-days, per capita income, fuel price, and the average size of a housing unit by state for the calendar year 1970. A total of 212 communities were examined with 41 percent being in California. It was decided, therefore, that this methodology would be the most appropriate one to apply in this study even though there is a seven year lag time.

Table 4-3. COUNTIES NOT UTILIZING FUEL OIL IN THE RESIDENTIAL SECTOR

Alameda	San Bernardino
Contra Costa	San Diego
Imperial	San Francisco
Kern	San Luis Obispo
Los Angeles	San Mateo
Marin	Santa Barbara
Monterey	Santa Clara
Napa	Santa Cruz
Orange	Solano
Riverside	Sonoma
Sacramento	Sutter
San Benito	Ventura
	Yolo

The formula used is as follows:

$$R_i = [0.092(D_i) + 217\ (H_i) - 568]\ (S_i) + 250\ (W_i) \qquad \underline{1}$$

where,

R_i = distillate oil consumption rate in the county's residential sector (gal/yr)

D_i = annual heating degree-days in county i

H_i = average number of rooms per residential housing unit in county i

S_i = total number of residential housing units using distillate oil for space heating in county i

W_i = total number of residential housing units using distillate oil for water heating in county i

This analysis (as well as the U.S. EPA[7]) defines the residential sector as including only housing units in structures of less than 20 units. Limiting the residential sector in this way imparts validity to the assumption that all residential fuel oil burned is distillate oil. The term "heating degree-days" is defined as a measure of the departure of the mean daily temperature from 65°F: one degree day for each degree of departure below the standard of 65°F during one day.

For each county in question, 1977 heating degree-day data were extracted from the Climatological Data publication.[9] It was necessary, however, to formulate criteria to determine which stations (those with heating degree-day data) were in close proximity to the residential areas. From examining the geographic location of the stations, it was found that station elevation is a reasonable indicator of location with respect to residential areas. Moreover, with two exceptions, it was determined that stations below the 4,500 feet elevation level would yield representative data for these areas. The first exception was Tahoe City in Placer County, with an elevation of 6,230 feet. Due to winter resort business of the Lake Tahoe area, this station's data was included based on the population of this city to that of other cities in the area. The other exception was in Sierra County, with only one station reporting (elevation 4,975 feet). Overall, when there was more than one station reporting for each county, the arithmetic mean was taken.

The average number of rooms (variable H) per household unit in each county was obtained from the 1970 Census of Housing.[4] It was assumed that the 1970 information is reflective of 1977 conditions.

Both the magnitude of the housing stock using distillate oil for space heating (variable S) and the magnitude of the housing stock using distillate oil for water heating (variable W) were derived from 1970 Census information.[4] The methodology used to determine these values as well as that used to update the 1970 totals to 1977 is described in Appendix A. The results are shown in Table 4-4 along with the data for variables D and H.

The fuel oil consumption estimates resulting from the execution of the algorithm are shown in Table 4-4. Also indicated are the ARB's 1977 estimates for the corresponding counties. One can see that there is good agreement between the estimates generated by two different approaches. Consequently, these are taken as truly reflective of the actual consumption during 1977.

4.2.3 TEMPORAL PATTERNS

As part of their work in forecasting energy demand in the state, the California Energy Commission partitioned the state into 11 basic meterological zones. The Energy Commission further subdivided the zones into a total of 15.[2] Although these climatic zones were created so as to allow accurate forecasting of electricity in the state, it is reasonable to assume that fuel oil usage patterns in the residential sector will follow the same climatic zones.

Table 4-5 indicates which Energy Commission designated zone each of the counties in question resides. To generate a usage pattern for the four zones shown in the table, heating degree-days data[9,10] by month were examined. Table 4-6 presents the results of this analysis. It should be noted that these patterns are for energy used in space heating since energy consumption for water heating is taken as being uniform throughout the year.

Rather than providing a graph depicting each county's temporal pattern, a composite of each county pattern was generated. This is provided in Figure 4-1.

Table 4-4. ESTIMATED FUEL OIL CONSUMPTION FOR RESIDENTIAL SECTOR, 1977

County	VARIABLE				PES Estimate[a]	ARB Estimate[a,b]
	D	H	S	W		
Alpine	6,020	3.8	76	0	42	166
Amador	3,280	4.5	373	0	265	260
Butte	3,350	4.7	630	19	484	444
Calaveras	2,790	4.4	184	0	118	130
Colusa	3,080	4.8	77	0	58	501
Del Norte	4,440	4.5	512	17	422	431
El Dorado	4,160	4.5	1,100	213	924	1,080
Fresno	5,060	4.9	1,070	253	1,090	647
Glenn	2,920	4.9	173	17	136	100
Humboldt	4,290	4.7	975	34	834	775
Inyo	3,040	4.2	347	32	224	297
Kings	2,460	4.9	100	59	87	69
Lake	3,140	4.2	814	40	525	995
Lassen	6,250	4.6	1,180	56	1,200	934
Madera	2,600	4.7	86	0	59	59
Mariposa	4,880	4.1	212	16	167	253
Mendocino	3,560	4.5	2,120	181	1,610	1,550
Merced	2,280	4.8	307	23	216	206
Modoc	6,780	4.8	708	53	790	508
Mono	6,020	4.4	295	57	292	492
Nevada	4,900	4.7	2,430	229	2,250	1,740
Placer	3,440	4.8	1,450	133	1,180	1,060
Plumas	5,850	4.5	1,060	38	1,010	955
San Joaquin	2,880	4.7	519	0	372	335
Shasta	4,100	4.7	1,080	17	900	709
Sierra	6,950	4.1	343	0	330	131
Siskiyou	5,480	4.6	2,240	51	2,110	1,740
Stanislaus	2,680	4.9	374	46	289	223
Tehama	2,690	4.8	495	0	357	354
Trinity	4,940	4.0	207	0	156	206
Tulare	2,510	4.8	533	24	382	342
Tuolumne	4,090	4.5	131	48	115	131
Yuba	2,580	4.7	259	0	178	187
State Total					19,200	

[a] Expressed in thousands of gallons per year
[b] Reference 5

Table 4-5. METEOROLOGICAL ZONING OF SUBJECT COUNTIES

METEOROLOGICAL ZONE			
IA	IIA	IB	IIB
Alpine	Amador	Inyo	Butte
Calaveras	Placer	Mono	Colusa
Del Norte	San Joaquin		Fresno
El Dorado			Glenn
Humboldt			Kings
Lake			Madera
Lassen			Merced
Mariposa			Shasta
Mendocino			Stanislaus
Modoc			Tehama
Nevada			Tulare
Plumas			Yuba
Sierra			
Siskiyou			
Trinity			
Tuolumne			

Table 4-6. TEMPORAL PATTERN FOR METEOROLOGICAL ZONES (PERCENT)

MONTH	METEOROLOGICAL ZONE			
	IA	IIA	IB	IIB
Jan	16	22	21	24
Feb	13	16	16	17
Mar	13	13	13	14
Apr	9	8	7	7
May	6	4	3	2
June	3	0	1	0
July	1	0	0	0
Aug	2	0	0	0
Sep	3	0	1	0
Oct	7	3	6	2
Nov	12	13	13	12
Dec	15	21	19	22

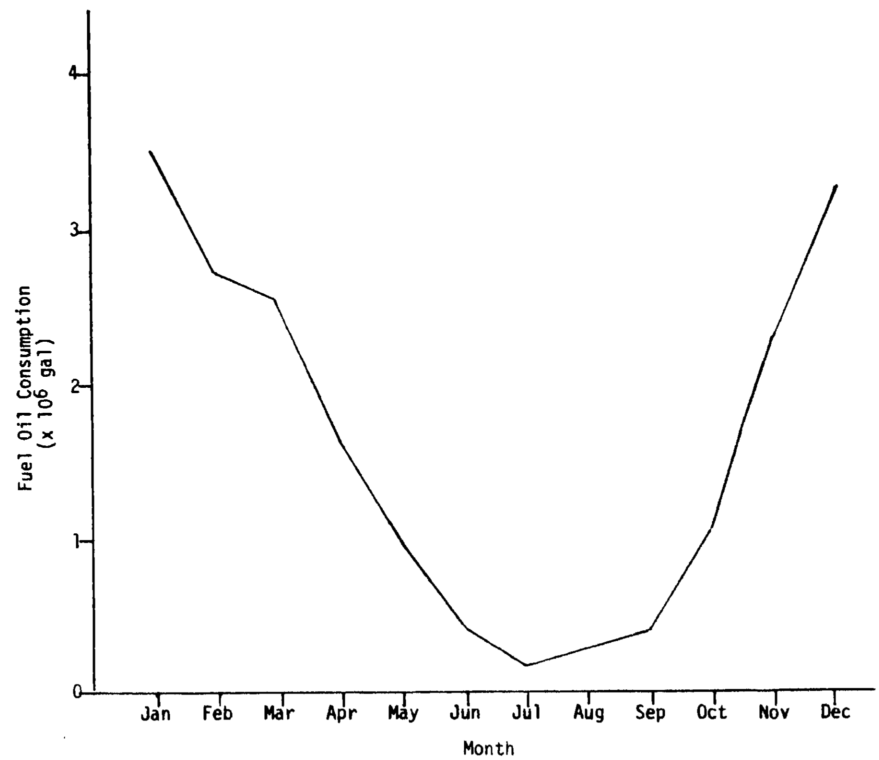

Figure 4-1. Consumption Pattern for the Residential Sector at the State Level, 1977

4.3 AGRICULTURAL SECTOR

4.3.1 GENERAL

Except for mobile farm equipment, fuel oil usage in the agricultural sector occurs primarily during irrigation, frost protection, and processing operations. Detailed quantification of fuel oil in this sector is not routinely performed except in the case of processing plants which are normally considered point sources. In fact, as a result of a literature search and from conversations with people in the industry, it appears that the most recent work in these areas is summarized in two reports: "Energy Requirements for Agriculture in California"[11] and "Pumping Energy Requirements for Irrigation in California".[12] Both studies were the result of a collaborative effort between the California

Department of Food and Agriculture and the Division of Agricultural Sciences at the University of California, Davis.

It is of particular interest that the findings of the studies indicate that approximately 18 percent of all energy consumed in this sector during 1972 was in the form of fuel oil (estimated to be 290 million gallons). Of this total, about 2 percent was consumed during irrigation, around 20 percent for frost protection, and the remaining 78 percent for such activities as farm vehicles and processing. Furthermore, the authors, as well as others (e.g., County APCDs and County Agricultural Commissioners), indicate that the nonvehicle fuel oils consumed in this sector are predominately middle distillates such as No. 2 or diesel.

The remaining portions of this section outline the methodology development and subsequent execution for estimating fuel oil usage in the two area source categories: irrigation and frost protection. This study has chosen to treat processing operations as point sources to be described later in Section 4.4. In general, processing operations come under SIC Major Group 20, "Food and Kindred Products", while the area sources tend to fall under SIC Major Group 01, "Agricultural Production - Crops".

4.3.2 ANNUAL ESTIMATES FOR IRRIGATION

To date, no previous study performed for the state has attempted to quantify the use of fuel oil for irrigation purposes at the county level. Moreover, there does not appear to be a readily available algorithm short of a survey that will yield these estimates. This is due, in part, to the extensive use of electric motors in generating the required pumping energy.[11,12] For instance, it has been estimated that over 95 percent of the irrigation pumping energy in California during 1972 was supplied by electricity.[13] Thus, it is understandable that energy related and emissions related inventories have traditionally considered fuel oil usage by this source to be of negligible impact. It was the intent of this phase of the study to either validate or dispel this assumption.

By far the most effective method with which to assess this source would be to conduct a survey of the various farms. However, this was quickly dismissed since there are some 68,000 farms in California.[13]. Even a carefully selected sample of approximately 10 percent would greatly exceed the scope of this task. Consequently, PES developed a method to estimate fuel oil consumption at the county level using readily available data. The following describes this methodology along with its execution.

There are several factors that influence the use of energy in irrigation pumping practices. These include, but are not limited to:

- climate
- soil
- topography
- source, availability, and quality of water
- energy requirements to bring water to the field
- crop type

In considering these various factors during methodology development, the report entitled "Pumping Energy Requirements for Irrigation in California" was extensively relied on.[12] This study estimated the electrical energy requirements for this activity during 1972. In order to minimize errors due to climate, soil type, and topography, the report subdivided the state into the 16 hydrologic basin planning areas defined by the State Water Resources Control Board (refer to Figure 4-2). These basins were then used as the basic geographic areas for all energy calculations. To be consistent, this study considers the same geographic areas.

In the 1972 study, the irrigated crop acreage in each hydrologic basin was first apportioned into four basic crop groups. Table 4-7

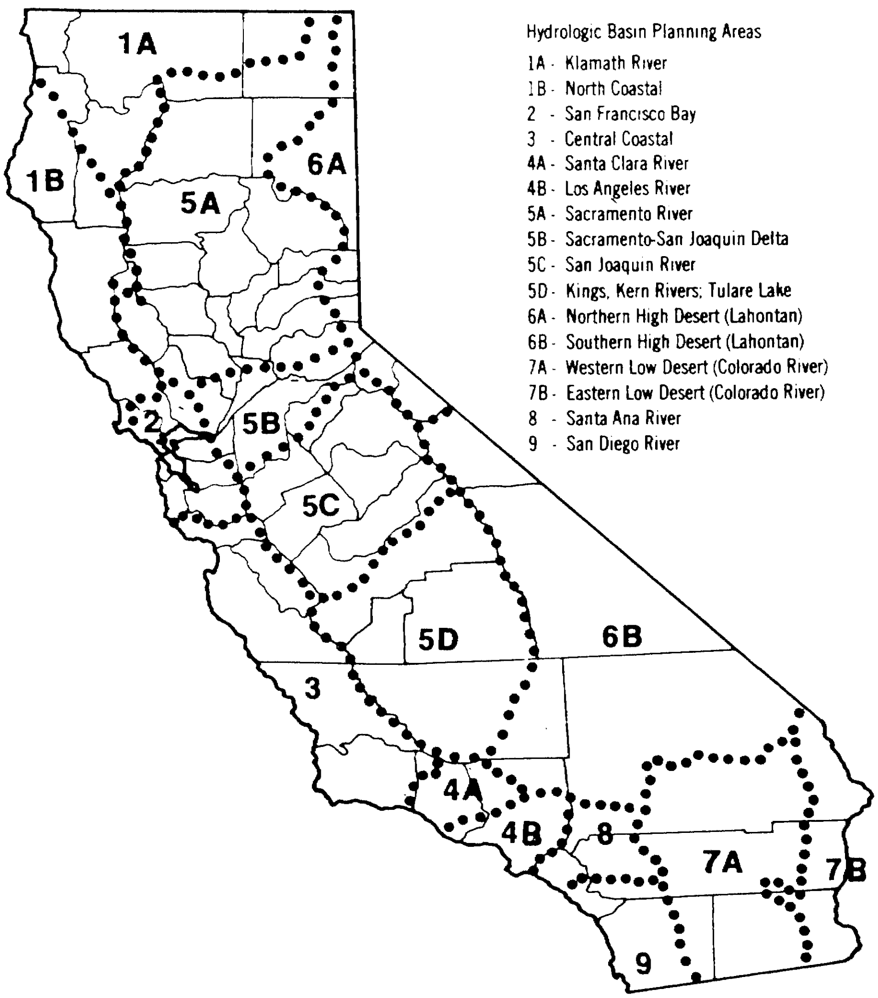

Figure 4-2. Hydrologic Basins

indicates these four groups along with the crops encompassed by each of the major categories. Data in the 1972 study presented estimates of the kilowatt-hours (kw-hr) per acre for each crop in each crop group within the hydrologic basin. These data were subdivided further into the following:

- on-farm well
  - surface irrigation
  - sprinkler irrigation
- surface water (water project and irrigation district water)
  - surface irrigation
  - sprinkler irrigation

Table 4-7. MAJOR CROP GROUPS

Group I Field Groups	Group II Fruit & Nut Crops	Group III Vegetable Crops	Group IV Pastureland
Alfalfa Small Hay & Grain Cotton Rice Sugar Beets Grain Sorghum Corn Other	Grapes Citrus[a] & Avocadoes Peaches & Nectarines Prunes Almonds Walnuts Other[b]	Beans Tomatoes Potatoes Lettuce Other	Irrigated Pastures

[a]Includes grapefruit, lemons, limes, oranges, tangerines, tangelos and tangors.
[b]Includes, among others, apples, apricots, cherries, pears, plums, dates and figs.

To illustrate the format of these data, Table 4-8 contains a sample of the manner in which the study data were presented. It should be reemphasized that these data represent the calendar year 1972.

As indicated in previous sections, the calendar year 1977 was one of the state's drought years. It was, in fact, the driest period in the last 50 years. The height of the drought occurred during 1976-1977 which resulted in an increase in groundwater well depths in the Central Valley. The remaining parts of the state experienced little or no change in well water depths. Consequently, before computing energy consumption estimates for 1977, an adjustment to the 1972 figures for those areas affected by the drought was necessary.

The information presented in Table 4-9 was employed in the adjustment process to take into account the additional energy required for irrigation in those hydrologic basins affected by the drought. Thus, the energy per acre for each crop in affected basins was estimated by the use of the following formulas:[12]

Surface Irrigation

$$e_{sij} = (da_i)_j \qquad \underline{2}$$

Sprinkler Irrigation

$$e_{kij} = [d_j + 216]\, a_{ij} \qquad \underline{3}$$

where

e = energy factor (kw-hr/acre) for crop that is surface irrigated (s) or sprinkler (k) by either on-farm well water or surface water.

d = drought year energy factor (kw-hr/acre-feet), not including sprinkler head pressure, for either surface or sprinkler irrigation as appropriate (Table 4-9).

216 = additional energy required for a sprinkler head pressure of 126 feet. In units of kw-hr/acre-feet.

Table 4-8. EXAMPLE OF ENERGY FACTORS FOR HYDROLOGIC BASIN 4A[a]
(kw-hr/acre of irrigated crop)

CROPS	On Farm Well (89.7% of Acreage)		Surface Water (10.3% of Acreage)	
	Surface Irrigation	Sprinkler Irrigation	Surface Irrigation	Sprinkler Irrigation
Field Crops				
Alfafa	720	1,307	1,297	1,769
Sugar Beets	---	1,340	---	1,812
.				
.				
.				
etc.				

[a]Refer to Appendix B for complete listing.

Table 4-9. COMPARISON OF ESTIMATED IRRIGATION ENERGY REQUIREMENTS DURING NORMAL YEARS AND THE HEIGHT OF THE 1976-77 DROUGHT[a]
(kw-hr/acre ft)

Hydrologic Basin	Surface Irrigation		Sprinkler Irrigation	
	Normal Year	Drought Year	Normal Year	Drought Year
5A	91	105	308	321
5B	153	167	370	384
5C	212	219	429	435
5D	312	324	528	540

[a]Reference 8. The other hydrologic basins were indicated to have experienced little or no effect.

a = Average water applied during 1972 (assumed to be reflective of 1977) (Table 21 through 36 of Reference 12).

ij = In units of acre-feet/acre crop i in hydrologic basin j.

In the case of the crops in the other hydrologic basins, the 1972 estimated energy per acre requirements are assumed to reflect the conditions of 1977.

In general, the remaining portion of the methodology development involves the aggregation of these energy factors into weighted averages by major crop in each hydrologic basin. County estimates are generated by coupling these factors with appropriate crop acreage information in an equation that allows for energy conversions and fuel distribution (i.e., electricity to fuel oil).

Thus, the next step was to obtain an average energy requirement per acre for each crop within each hydrologic basin. These weighted averages were calculated using the following:

$$\overline{e}_{ij} = \left\{ [(F)(e_{sf}) + (W)(e_{sw})](c_s/c) + [(F)(e_{kf}) + (W)(e_{kw})](c_k/c) \right\}_{ij} \qquad \underline{4}$$

where,

$\overline{e}_{ij}$ = weighted average energy factor (kw-hr/acre) for crop

F = fraction of crop acreage that is irrigated from on-farm well

e_{sf} = energy factor for crop that is surface irrigated from on-farm well

W = fraction of crop acreage that is irrigated by surface water

e_{sw} = energy factor for crop that is surface irrigated by surface water

c_s = total crop acreage that is surface irrigated

c = total crop acreage

e_{kf} = energy factor for crop that sprinkler irrigated from on-farm well

e_{kw} = energy factor for crop that is sprinkler irrigated by surface water

c_k = total crop acreage that is sprinkler irrigated

ij = crop i in hydrologic basin j

The following example using the data for alfalfa from Table 4-8 along with 1972 crop data illustrates the use of this equation.

[(0.897)(720 kw-hr/acre)+(0.103)(1297 kw-hr/acre)](325/935) +
[(0.897)(1307 kw-hr/acre) + (0.103)(1769 kw-hr/acre)](610/935)
= 1150 kw-hr/acre

The results of this equation were then used to compute a weighted average energy factor for each major crop group within each hydrologic basin. This task was accomplished by the formula:

$$E_{gj} = \frac{1}{c_{tgj}} \sum_{i=1}^{N=4} [(\bar{e}c)]_{igj} \qquad \underline{5}$$

where,

E = weighted average energy factor (kw-hr/acre) for crop group

c_t = total crop group acreage

$\bar{e}$ = weight acreage energy factor for crop i

c = total acreage for crop i

gj = crop group g in hydrologic basin j

Once these numbers were calculated, an additional adjustment was necessary. As noted earlier, the data from the 1972 study estimated that over 95 percent of the irrigation pumping energy in California was supplied by electricity. To simulate 100 percent electrical energy and to make a conservative estimate of the total overall energy demand, each of the energy factors (Egj) were divided by 0.95. These new factors, which are shown in Table 4-10, are estimates of total energy demand since the original energy factors took into account pump efficiencies.

The final step was to combine the energy factors from Table 4-10 with the appropriate crop acreage estimates from Appendix B in the equation:

$$A = \frac{H_e RF}{H_f} \sum_{i=1}^{N=4} (Ec_t)_i \qquad \underline{6}$$

where,

A = distillate oil consumption rate for irrigation in county (gal/yr)

H_e = heat content for electricity (3,410 Btu/kw-hr)[10]

H_f = heat content for distillate oil (140,000 Btu/gal)[10]

R = efficiency ratio of electric powered pumps to distillate powered pumps

F = fraction of total irrigation pumps in California that were distillate powered

E = energy factor for crop i in hydrologic basin where county is located (Table 4-10)

c_t = total county acreage of crop group i (Appendix B)

From examining various references,[2,12,14,15] the efficiency ratio factor was taken to be 1.72. In the case of the F factor, the

Table 4-10. MAJOR CROP GROUP ENERGY FACTORS BY HYDROLOGIC BASIN (kw-hr/acre)

Hydrologic Basin	Group I	Group II	Group III	Group IV
IA	214	897	512	1,540
IB	293	651	675	1,140
2	1,110	946	978	1,690
3	661	666	468	1,240
4A	1,140	703	487	1,460
4B	1,860	1,430	2,200	2,790
5A	230	486	166	272
5B	282	479	253	445
5C	953	970	568	1,240
5D	1,200	1,190	1,120	2,200
6A	214	0	477	779
6B	1,550	1,430	1,060	1,570
7A	60	136	107	50
7B	35	49	71	43
8	1,720	1,730	2,050	2,340
9	3,450	3,950	4,430	6,730

[a]No group II crops in this basin.

Irrigation Journal[16] reports that during 1977 about 8 percent of all irrigation pumps in California were distillate (diesel) powered.

The final results of this methodology are shown in Table 4-11.

4.3.3 ANNUAL ESTIMATES FOR FROST PROTECTION

During the course of developing fuel oil estimates for frost protection activities in California, it was determined that there are five basic methods: orchard heaters, wind machines, helicopters, sprinkler systems, and furrow irrigation. Energy required by sprinkler systems and furrow irrigation was included as part of PES' estimates for irrigation. As such, they are not reported separately. In addition, the energy requirement for the application of helicopters for frost protection is also not reported since they burn aviation gasoline and are therefore outside the scope of this study.

Both orchard heaters, or "smudge pot" as they are sometimes called, and wind machines burn middle distillates (diesel) for their source of fuel. Although this is the dedicated fuel for heaters, wind machines may also use electricity, gasoline, or LPG.

During the course of this study, it was learned that there is no "rule of thumb" for determining frost protection practices in the state. The decision on which type of equipment to use, and under what conditions, is made by each grower. In making these decisions, each grower weighs the economic feasibility of frost protection. This entails considering such factors as the cost of frost protection, total grove costs, value of trees and crop, and probable life of the orchard. Consequently, frost protection activities from district to district or even grove to grove vary considerably.

There have been attempts to quantify these practices, but so far they have proved to be unsatisfactory. Collectively, these attempts have involved determining the total number of orchard heaters either by an actual county count or by algorithm, then estimating their

Table 4-11. ESTIMATED FUEL OIL CONSUMPTION FOR IRRIGATION, 1977

County	Hydrologic Basin[a]	Fuel Oil Consumption[b]
Alameda	2	41
Alpine	6A	0
Amador	5B	7
Butte	5A	213
Calaveras	5B	5
Colusa	5A	224
Contra Costa	2	193
Del Norte	1A	24
El Dorado	5A	11
Fresno	5C/5D	4,060
Glenn	5A	153
Humboldt	1B	78
Imperial	7A/7B	125
Inyo	6B	70
Kern	5D	3,510
Kings	5D	2,260
Lake	5A	39
Lassen	6A	71
Los Angeles	4A/4B	278
Madera	5C	1,030
Marin	2	3
Mariposa	5C	Neg
Mendocino	1B	54
Merced	5C	1,340
Modoc	5A	102
Mono	6B	73
Monterey	3	483
Napa	2	84
Nevada	5A	8
Orange	9	259
Placer	5A	40
Plumas	5A	30
Riverside	8	1,440
Sacramento	5B	208
San Benito	3	80
San Bernardino	8	337
San Diego	9	785
San Francisco	2	0
San Joaquin	5B	573
San Luis Obispo	3	309
San Mateo	2	13
Santa Barbara	3	195
Santa Clara	2	110
Santa Cruz	3	50
Shasta	5A	53
Sierra	6A	30
Siskiyou	1A	613
Solano	5B	181
Sonoma	1B/2	144
Stanislaus	5C	980
Sutter	5A	243
Tehama	5A	112
Trinity	1A	2
Tulare	5D	2,430
Tuolumne	5C	9
Ventura	4A	209
Yolo	5A	104
Yuba	5A	88
State Total		24,200

[a] Ratios are taken to be 50:50
[b] Expressed in thousands of gallons per year

on-line time and hourly fuel consumption rate. It is usually the case, however, that all of the estimated heaters are not operated at the same time due to their use in conjuction with wind machines. It may also be true that although the estimated population of heaters is a "good" number they are not used at all due to water technology coming on-line. This conclusion was verified during the study when it was learned that water technology for frost protection has been replacing heaters at a rapid pace. In fact, most vineyards in the state are currently being protected by sprinkler systems.

In studying this highly complex source category, it was decided that the best approach to the problem would require contacting local agricultural agencies and county APCDs to qualify the practices in each county. A sample survey of growers was considered, but because of the high variability of practices from grove to grove this inventory technique was dismissed.

Through local contacts and readily available documents, it was determined that fruits are the predominate crops requiring frost protection. Based on reference 11, a survey of Agricultural Extension Farm Advisors in 14 counties, and the subsequent analysis for the calendar year 1972, the fruit crops were aggregated into three groups: deciduous fruits and nuts, citrus, and grapes. A phone survey of local agricultural agencies was conducted to query officials about frost protection activities for these three crop groups. The data gathered centered around the number of crop group acres protected by heaters and/or wind machines, equipment densities (i.e., units per acre), and operating patterns. This information was coupled with that collected during the county APCD visits. Appendix B documents the most important information extracted from these contacts while Table 4-12 lists the counties not using fuel oil for frost protection during 1977. Further, Table 4-13 compiles these data for those counties using fuel oil during 1977 in numeric

Table 4-12. COUNTIES NOT USING FUEL OIL FOR FROST PROTECTION ACTIVITIES, 1977

Counties Identified As Not Using Orchard Heaters Or Wind Machines During 1977	Counties Identified as Not Having Freeze Days During 1977
Alameda	Alpine
Alpine	Del Norte
Colusa	Humboldt
Contra Costa	Inyo
Inyo	Kings
Lassen	Lassen
Mono	Modoc
Plumas	Mono
San Diego	Orange
San Francisco	Sacramento
Santa Clara	San Benito
Sonoma	San Luis Obispo
Yolo	Shasta
	Sierra
	Siskiyou
	Trinity
	Tuolumne

Table 4-13. ESTIMATED FUEL OIL CONSUMPTION FOR FROST PROTECTION, 1977

County	PROTECTED ACREAGE[a]			Estimated Number of Days Requiring Frost Protection[e]	Fuel Oil Consumption[f]
	Deciduous Fruits & Nuts	Citrus	Grapes		
Amador	1,040 (d)	0	938 (d)	45	18
Butte	4,380 (b)	0		2	127
Calaveras	1,370 (d)	0	65 (d)	46	14
El Dorado	3,770 (d)	0	177 (d)	89	73
Fresno	3,470 (b,c)	21,000 (d)		3	2,580
Glenn	400 (b)	150 (b)		1	57
Imperial	0	540 (b)		1	62
Kern		30,000 (b,d)		2	1,150
Lake	8,600 (b,c)	0		27	1,710
Los Angeles	1,640 (c,d)		0	2	63
Madera		3,940 (c)		5	105
Mendocino[g]					883
Merced	3,500 (b)			1	202
Monterey	400 (d)			8	1
Napa		0	15,800 (c)	4	695
Nevada	143 (d)	0	0	38	1
Placer	3,500 (d)	42 (d)	295 (d)	68	54
Riverside		7,200 (b,c)		13	1,800
San Bernardino		1,600 (c)		33	2,040
San Joaquin	1,200 (b,c)			3	67
San Mateo	233 (d)	0	0	1	Neg
Santa Barbara	5,470 (d)	3,840 (d)	5,890 (d)	3	10
Santa Cruz	8,000 (d)	57 (d)		16	27
Solano	17,000 (d)	0	1,650 (d)	11	42
Stanislaus	4,200 (c)			2	363
Sutter	51,300 (d)	0	0	1	11
Tehama	34,600 (d)	0	307 (d)	2	11
Tulare	120 (b)	43,000 (c,d)		9	2,090
Ventura	970 (c)	4,400 (c)	0	7	187
Yuba	4,760 (d)	0	700 (d)	22	25
State total					14,500

[a]Data was compiled by analyzing data from Reference 11, 17, 18 and Appendix B. Blanks indicate that the crop is protected by some other means

[b]Protected by orchard heaters only

[c]Protected by orchard heaters with wind machines

[d]Protected by wind machines only

[e]Reference 5

[f]Expressed in thousands of gallons per year

[g]Refer to Appendix B

Table 4-14. TYPICAL PARAMETERS FOR FROST PROTECTION EQUIPMENT

Parameters	Orchard Heaters	Wind Macnines
Unit Density	15 units/acre[b]	1 unit/10 acres
	30 units/acre[c]	
Fuel Consumption[d]	0.96 gal/hr	0.92 gal/hr
Operating rate[d]		
- Deciduous Fruits, nuts and grapes	3 hrs/night	7.5 hrs/night
- Citrus	4 hrs/night	10 hrs/night

[a] 30 percent of total population is taken to be distillate powered
[b] with wind machines
[c] without wind machines
[d] value per unit

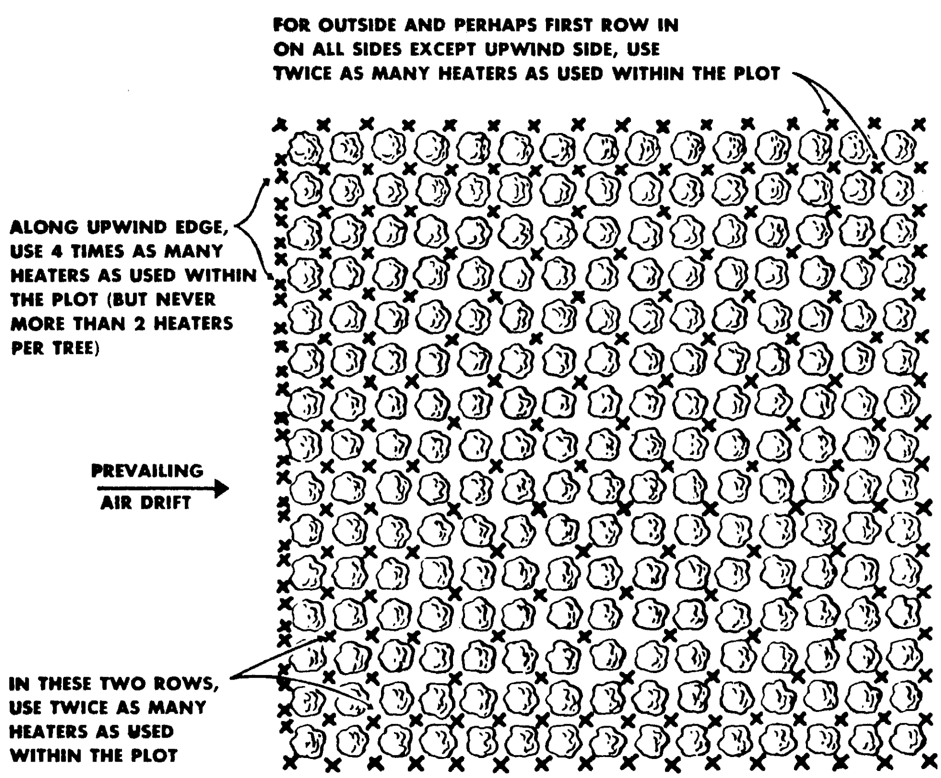

Figure 4-3. Typical example of orchard heating spacing[20] (Based on using one heater per two trees. Small crosses indicate heaters)

format. Where necessary, information from the 1972 study was used to generate estimates of protected crop acreage and equipment patterns.

Wherever possible, actual data for fuel consumption rates, equipment densities, and operating time were used. In those cases where this was not possible, the values shown in Table 4-14 were taken as being representative. These values were the result of examining the information collected through local agency contacts and by reviewing various documents.[11,19,20,21]

It should be noted that the unit density figures in Table 4-14 are rough estimates. This is due to the problem of heater location for each discrete section of a protected grove. The location of the heaters has a great deal of influence upon the total amount of radiant heat received by the trees, and upon the uniformity of the distribution of the trees. Figure 4-3 illustrates this point for a grove with protection by heater only. The same configuration applies to those cases where wind machines are used in conjunction with heaters, although the heater density is much lower. The unit density figures used in this study have taken this in account. Consequently, to generate a better estimate would require, at a minimum, knowing the typical plot size of the groves in each county. This in turn would require a sample survey of the farms in each area.

Each county's fuel oil consumption estimate (refer to Table 4-13) was calculated by first determining the fuel usage per frost night then by multiplying by the number of frost nights during the year (refer to Table 4-14). In some cases, the actual operating time was determined through local contacts. As can be seen, the calculating sequence was not the result of an algorithm in terms of that used for irrigation, but rater was done on a case-by-case basis.

4.3.4 TEMPORAL PATTERNS

As indicated earlier, electricity is the primary source of power for irrigation in the state. It is thus reasonable to assume that the monthly consumption patterns for fuel oil would be congruent with the electricity demand pattern. With this in mind, Table 4-15 indicates these patterns for various geographical areas of the state. From the references cited, it was determined that these are reasonable patterns for the counties they encompass. Table 4-16 shows this distribution.

In the case of frost protection, the high variability in the operating time within a given district makes quantification of the actual temporal pattern very difficult. Thus, for purposes of this study it was decided to construct generalized temporal patterns for the counties in question. From examination of climatological data,[9] its fairly evident that frost protection activities occur predominately in the winter quarter. Further examination suggests a temporal pattern of 50 percent, 20 percent, 10 percent and 20 percent for January, February, November and December, respectively.

Figure 4-4 graphically displays an overview of the agricultural's monthly consumption pattern at the state level.

4.4 INDUSTRIAL, COMMERCIAL AND INSTITUTIONAL SECTORS

4.4.1 GENERAL

The approach used in developing accurate and complete information for industrial, commercial and institutional establishments involved an aggressive questionnaire survey of all potential fuel oil sources in these sectors. This approach, by far, was the most resource intensive but it also provided the most effective method to gather all necessary data.

Table 4-15. TEMPORAL PATTERN FOR GEOGRAPHICAL AREAS

MONTH	SACRAMENTO VALLEY	SAN JOAQUIN VALLEY	REMAINDER OF STATE	
			A	B
Jan	0	0	3	0
Feb	0	10	5	0
Mar	0	4	1	1
Apr	12	11	1	1
May	19	13	7	7
Jun	20	19	13	15
Jul	20	20	20	22
Aug	20	14	20	22
Sep	9	3	20	22
Oct	0	3	10	10
Nov	0	0	0	0
Dec	0	3	0	0

[a]Profiles developed from contact with local agricultural agencies and Reference 22.

[b]A = counties where cotton is a large fraction of the total crops.
B = counties where cotton is a small or zero fraction of the total crops.

Table 4-16. GEOGRAPHICAL DISTRIBUTION OF COUNTIES

SACRAMENTO VALLEY	SAN JOAQUIN VALLEY	REMAINDER OF STATE		
		A	B	
Butte	Fresno	Imperial	Alameda	Orange
Glenn	Kern	Riverside	Alpine	Placer
Sacramento	Kings		Amador	Plumas
Sutter	Madera		Calaveras	San Benito
Tehama	Mariposa		Colusa	San Bernardino
Yolo	Merced		Contra Costa	San Diego
Yuba	San Joaquin		Del Norte	San Francisco
	Stanislaus		El Dorado	San Luis Obispo
	Tulare		Humboldt	San Mateo
	Tuolumne		Inyo	Santa Barbara
			Lake	Santa Clara
			Lassen	Santa Cruz
			Los Angeles	Shasta
			Marin	Sierra
			Mendocino	Siskiyou
			Modoc	Solano
			Mono	Sonoma
			Monterey	Trinity
			Napa	Ventura
			Nevada	

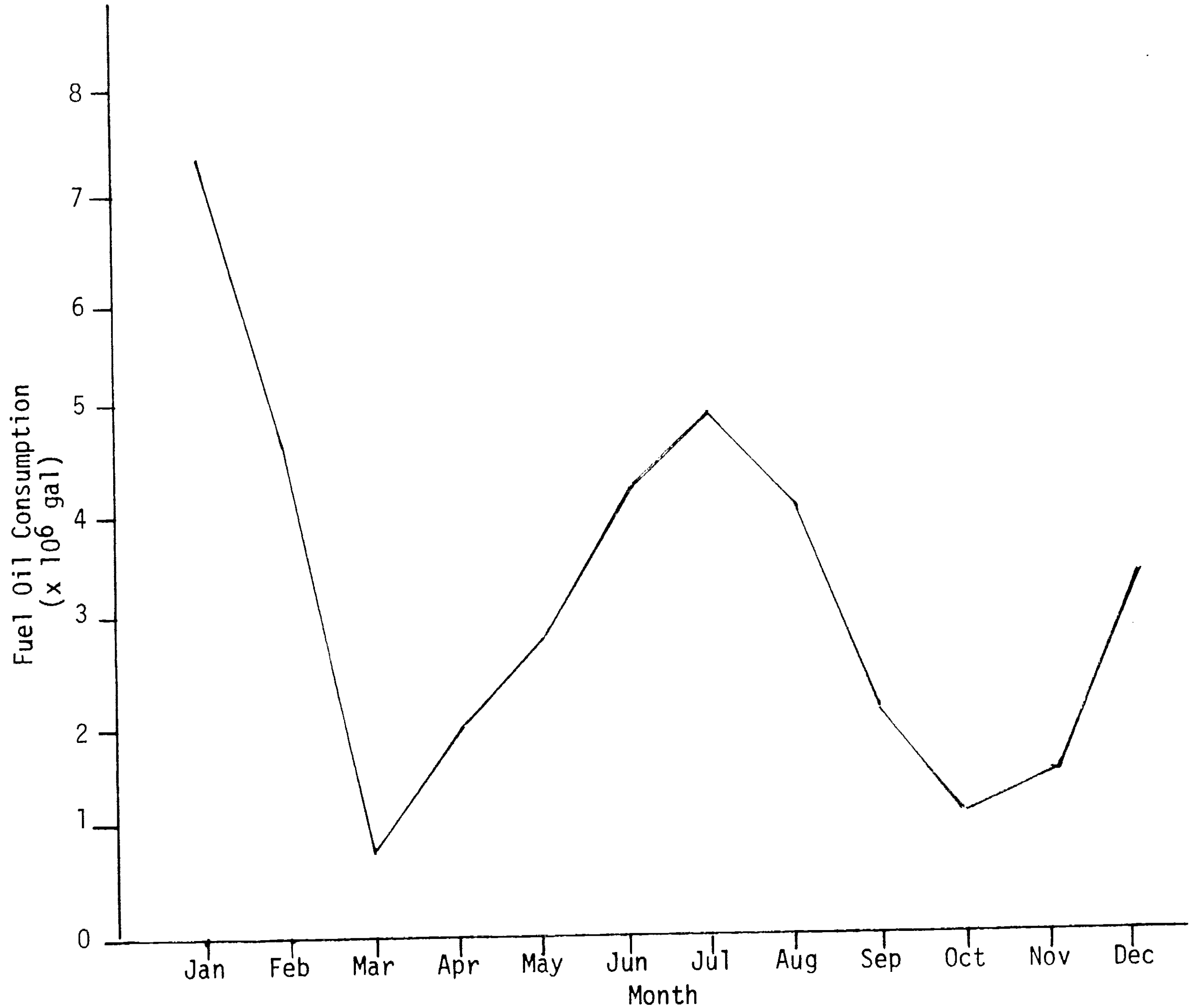

Figure 4-4. Consumption Pattern for the Agricultural Sector at the State Level, 1977

The aggressive questionnaire survey included the successful execution of the following key elements.

- Development of a complete source list of potential fuel oil users,
- Design of an effective questionnaire package,
- Mailing of the questionnaire package to all sources,
- Logging and analysis of the questionnaire returns,
- Recontacting of the major fuel oil users who did not respond to the initial mailing, and
- Summarizing the results.

The following discussions provide detailed descriptions of execution of the those key elements.

4.4.2 MAILING LIST DEVELOPMENT

The industrial sector consists of a wide variety of facilities encompassing all manufacturing establishments within SIC Major Groups 19 through 39. The commercial/institutional sectors, on the other hand, are encompassed by SIC Major Groups 50 through 98. These include, but are not limited to hotels, schools, hospitals, and military installations.

Upon first inspection, one is tempted to appraise these two sectors by sending fuel oil questionnaires to each establishment. However, there is a significant survey problem in that the Bureau of Census[22] data indicate approximately 36,000 establishments in the industrial sector and an enormous 200,000 in the other two sectors. Even conceding that the majority are not involved in the combustion of fuel oils, a mail survey of this magnitude would far exceed the scope of most inventories, including this one. Consequently, a methodology was required that would predetermine the most likely users of fuel oils.

Realizing that the common denominator of all fuel oil combustion is air pollutants, it was decided to use ARB and county APCD files as the basis for compiling a source list of potential fuel oil users. It was reasoned that these files would identify all but the very small sources due, in part, to each of the agencies permit and enforcement activities.

To acquire a statewide perspective, PES requested a copy of the current ARB EIS file which contains data on all California facilities emitting more than 25 tons per year of any criteria pollutant. An immediate problem emerged with this request since a significant number of data entries in the file contain confidential information relating to trade secrets. Consequently, the ARB legal staff decided to evaluate this request on legal grounds. After a rather lengthy review period, ARB's legal staff gave its permission for the release of the EIS file to PES, but only after all of the data deemed confidential were struck from the file. PES was instructed to either gather the necessary confidential data directly from the source or to gather it from the county APCDs.

Upon receiving the magnetic tape containing the EIS file, PES promptly compiled a selective source list based on combustion units within the appropriate Source Classification Codes (SCC). There were two rather surprising and puzzling discoveries made concerning data marked confidential (these were marked with "C" where data would have appeared). First, a cursory review of the fields that were marked confidential showed many were coded in informational categories normally not associated with trade secrets or other confidential data, such as fuel oil throughput. Secondly, many of the data for the SCAQMD (in some cases entire facility records and in all cases throughput data) were marked confidential. Therefore, it appeared that the exclusion of confidential data from the EIS file would be a major problem.

Closer investigation of the EIS file pointed out two additional problems associated with the use of these data.

- It was not possible to examine the file directly and determine with reasonable certainty which year the various data elements represented. In some cases, the data represented a calendar year (1977 in many instances), while others represented a fiscal year. Furthermore, from conversations with local APCDs, the date associated with some of the data elements was the date the data were entered into the file and not the year of record.

- PES performed a rather superficial quality assurance review on the file. Results from the review showed that there appeared to be a number of coding errors contained in the file, such as unit designation of individual data fields. As an example, in some cases the amount of fuel throughput for a combustion unit far exceeded the indicated design capacity of the unit while in other cases the designated UTM coordinates placed the facility in the Pacific Ocean. Again, discussions with local APCDs confirmed this suspicion. They stated that in many cases because of issues such as bugetary restrictions, inexperienced personnel, often students, were used to perform the coding task.

For these reasons, the data contained in the file could not be taken as being truly representative of the source on file. Furthermore, at the suggestion of some of the APCDs, it was decided to survey all of the facilities on this source list and if necessary only use these data after careful examination on a case-by-case basis. However, it should be emphasized that the EIS has recently been undergoing major revisions and updating through a collaborate effort between the ARB and local APCDs.

The next step in the development of the source list was visits to local APCDs to review their files firsthand. In all, 35 of the 44 local APCDs were visited. For 7 of the 9 agencies not visited, the necessary information was gathered by either telephone or correspondence. The remaining two, Yolo-Solano APCD and Santa Barbara APCD, declined to provide any assistance to PES for this study. Yolo-Solano APCD based their refusal on grounds of confidentiality.

Consequently, the source list for the three counties involved was compiled from the EIS file and the approach to be discussed later.

Of special note, to avoid any potential confidentiality problems with PES reviewing local agency files, two secrecy agreements were signed by PES (refer to Appendix C). The first document was a company secrecy agreement signed by a PES Corporate Officer, binding PES to preserve in strict confidence all "trade secret" information. The second document, "Employee Secrecy Agreement", bound each PES employee having access to such information to treat it within prescribed requirements. Notwithstanding the Yolo-Solano APCD, PES rarely encountered confidentiality problems either in APCD files or from the sources themselves.

Although it was thought that reviewing the APCD files would yield "hard data" on the EIS sources as well as provide the list of sources to fill the gap between large and negligible size sources, it was soon evident that the type and quality of data varied greatly from county to county. The following illustrates some general observations.

- Much of the data were found to not reflect the calendar year 1977 but rather some combination of earlier years.
- Some facility data only represented total fuel oil usage data for the entire plant (i.e., no equipment usage data).
- Fuel oil characteristics of the fuel being burned were practically nonexistent.
- Monthly temporal pattern data were generally not available.

Thus, a decision was made to use APCD file data to supplement the inventory. The APCD files were primarily used to assist in the development of an accurate source list of potential fuel oil users for the mail out survey. However, plant data were collected for use later as a source of information on the nonresponding sources. Finally, through these contacts it was learned that the local APCDs tend to have detailed knowledge of the industrial sources as a result of their enforcement activities, but are, in general, rather unaware of fuel oil users in the other two sectors covered under the study.

The principle reason for this unawareness on the part of the APCDs is two-fold. First, Many of the combustion units in the two sectors are of such size to be exempt from regulatory control thereby causing them not to be tracked. Secondly, some of the sources (those that indeed have fuel oil firing capability) may not have applied for a permit and/or may have never been inspected due, in part, to the fact that a complaint has never been filed. For the most part, the APCDs are understaffed and are currently experiencing difficult enforcement problems with industrial sources, therefore the tracking of these smaller sources is all but impossible.

Consequently, it was assumed that the industrial portion of the source list compiled through the EIS file and local APCD files was all inclusive except for a few small and probably nonconsequential sources. The source list for the other two sectors, however, required considerable further investigation. It was felt that an investigation of these presumably smaller sources was imperative for the accuracy required in the inventory.

Although there are a great number of types of establishments defined by the commercial and institutional group, the analysis was confined to the following categories based on the types of sources found in the APCD files.

- Hotels
- Schools
- Medical facilities
- Military facilities
- Correction facilities

The development of a potential source list for each of these categories was a function of a number of variables. The approach employed for each category is briefly discussed in the subsections that follow.

Hotels: To determine the use of fuel oil by hotels in the state, a telephone survey of the corporate offices of major hotel chains (e.g., The Sheraton Corp., Holiday Inns, Inc., Hilton Hotel Corp., Best Western International, etc.) was completed. In general, it was discovered that corporate offices do not always know what type of fuel each hotel uses, since each hotel tends to be a separate business entity in itself. Therefore, based on these contacts it was decided to survey all hotels of 100 rooms or more that were not already part of the source list. Corporate brochures and the Hotel & Motel Red Book[21] were used to identify these hotels.

Schools: Listings of all public and private schools in California were compiled from many sources. Each county in the state has several school districts which maintain the various public schools. For those counties identified as having no natural gas hookup, a standard fuel oil questionnaire was sent to each of the school district superintendents. To account for counties which are only partially served by natural gas, a telephone survey was conducted of the major school districts. Only those school districts with the largest percentage of the county enrollment were contacted since it was felt that these would be the most representative of the county. Those school districts that were identified as using fuel oil or propane for space heating were surveyed.

A phone survey of primary and secondary private schools located within each county with no natural gas hookup showed that these rural counties have relatively few private schools and have very low student enrollment. For example, Placer, Plumas, and Santa Clara Counties average less than 20 students per school, while Trinity County averages seven students per private school. As a result of the number and size of these schools, it was decided not to include them in the survey.

Private post-secondary schools (e.g., trade and fine arts) also were not surveyed. Most of these schools are private schools with a very specific field of study, such as dance, modeling, auto mechanics, and art. The vast majority of these schools are located in the Los Angeles and San Francisco metropolitan areas, which are serviced by natural gas.

Fuel oil is used on a standby basis at all California State and University of California schools. Those schools that were not already part of the source list were added because of their size. Independent institutions, such as Stanford University, Mills College, California Institute of Technology, Loyola, and Pepperdine were also surveyed.

Medical facilities: Facilities included in this category are hospitals, clinics, and extended care facilities. Extended care facilities include convalescent homes, nursing homes, and health sanitariums. An evaluation of the California Department of Health Services statewide list of health facilities revealed that free clinics and rehabilitation clinics are relatively small in size, have no overnight beds, and employ a very small staff. Thus, these facilities were not surveyed. In addition, company medical clinics were not surveyed since their energy consumption was presumed to be included with the company's energy consumption as a whole and thus would be addressed under the industrial sector.

A review of the State Department of Health Services' records on extended care facilities and hospitals indicated that the majority of the 800 facilities are located in the metropolitan areas of Los Angeles, San Diego, Sacramento, and San Francisco. A sample telephone survey of extended care facilities with 30 beds or more did not yield any fuel oil users. However, a few of these facilities do use fuel oil on a standby basis. In general, convalescent homes were found to use propane, butane or electricity for heating. Hence, these homes were not surveyed since they do not use fuel oil and generally house only between 20 and 30 patients.

Questionnaires were sent to all hospitals located in counties with no natural gas hookups. For counties with partial gas service, a sample phone survey was conducted of hospitals with more than 30 beds. If a hospital was found to use fuel oil in a particular county with partial gas service, then questionnaires were sent to all the hospitals in that county.

A sample telephone survey of hospitals in metropolitan areas indicated that no hospitals with less than 200 beds were fuel oil users. This was confirmed by reviewing the hospitals that were found in either the EIS or local APCD files. Thus, only large hospitals (i.e., hospitals with 200 beds or more) located in the metropolitan areas were added to the source list. Finally, all state mental institutions were surveyed.

Military facilities: A listing of military bases in California was obtained from each branch of the armed services. There are 70 principal military installations or activities in the state. All of these military bases not already on the source list were added.

Correctional facilities: PES received lists of state and federal penal institutions from the State Department of Corrections and the Federal Bureau of Prisons, respectively. All those facilities not on the original source list were included. It was determined not to query temporary incarceration centers, such as detention centers and jails, since they are usually located in the county courthouse, city hall or police station, and were included as part of the original source as appropriate.

4.4.3 DESIGN OF QUESTIONNAIRE PACKAGE

One of the areas that was given considerable attention was the design of the questionnaire package. The successful execution of this task can greatly enhance the response rate, thereby providing for a more reliable inventory. Care was taken in the design to provide for a structure which was as simple and functional as possible. In sum, the questionnaire package contained a cover letter, set of instructions, the questionnaire itself and a return postage paid envelope.

PES developed a short and direct cover letter which introduced the questionnaire, briefly stated the purpose of the inventory, cited appropriate California statutes that require a response from the recipient, outlined provisions for confidentiality, provided a response period and the names and phone numbers of individuals to contact regarding legal and technical questions.

Extreme care was taken to develop a concise and comprehensive set of instructions on how to fill out the questionnaire. The instructions judiciously explained pertinent information about the questionnaire as a whole and instructions for anticipated questions. Furthermore, the package contained enough instructions to provide guidance to those respondents with a nontechnical background in the subject area.

Finally, PES developed a questionnaire which included both general information questions about the facility (i.e., plant name, address, contact, nature of business) and specific questions concerning the usage of fuel oil (i.e., fuel oil type, heat, sulfur and nitrogen contents, combustion equipment design and operating parameters, and temporal resolution). Provided on the first page of the questionnaire (General Information) was a quick means by which a nonfuel oil using source could simply complete the brief general information section, check a no usage box and send the form back in a postage paid return envelope. This procedure, hopefully, enhanced the response rate of those nonfuel oil users who would have otherwise disposed of the questionnaire package immediately.

Again, as mentioned in the above, extensive effort was taken in developing the questionnaire to provide for the following:

- A simple (in relation to terminology) and concise form to especially enable its accurate completion by nontechnical respondents,
- functional relatedness for ease of filling out the form and transferring data to computer input,
- a vehicle by which additional data required by ARB in subsequent studies could be collected, thus reducing source annoyance in being surveyed repeatedly.

PES provided draft copies of the questionnaire package to ARB for review. Primary emphasis of the ARB review was placed on evaluation of the cover letter by ARB's legal council group. In addition, the questionairre was circulated among various technical ARB groups who might require additional information for potential future activities. After the review period, PES incorporated ARB's comments into the questionnaire package and forwarded them to the facilities on the source list. A copy of the questionnaire package is provided in Appendix C.

4.4.4 DATA ANALYSIS

The engineering analysis of each returned questionnaire was executed on a company by company, equipment by equipment, fuel type by fuel type basis. The equipment and fuel type used by the companies surveyed varied widely, thereby necessitating the development of a set of flexible guidelines for evaluating the data.

In analyzing information from the questionnaires, a certain amount of engineering judgement was required. Whenever possible, the data were used as reported by the respondents. However, when the data were highly suspect, such as one source's reported fuel oil consumption totals equaling about 7 percent of the national total, the source was contacted by telephone to resolve the discrepancy.

As mentioned earlier, the examination of the EIS and APCD files resulted in the presumption that the major users of fuel oil in 1977 were identified on the EIS file. Thus, greater effort was made in recontacting these nonrespondent sources as opposed to the minor nonrespondent sources (e.g., schools, hotels, hospitals, etc.). An attempt was made to contact all nonresponding EIS sources by telephone. Those sources which were not able to furnish the required data over the telephone were sent a second questionnaire. In those cases where sources did not have a current telephone number or were unwilling to respond to the second questionnaire, data were taken from the EIS/APCD files. It must be emphasized that these data were taken from the files only if they met certain criteria. These criteria included but were not limited to: (1) year of record had to be 1977, and (2) amount of fuel oil burned had to be consistent with type, capacity, and operating schedule of combustion unit.

Additional discussion of data analysis and the Automated Data Handling System (DHS) developed for this study is presented in Appendix C.

4.4.5 SURVEY RESPONSE RATES

In the context of this study, all sources in which PES could acquire the necessary data either by questionnaire, telephone or agency files were considered a positive response. The overall response rate for this phase of the study was 71 percent.

Table 4-17 summarizes the response distribution by county and further by EIS and non-EIS sources. The following briefly describes the code designations. They are discussed in more detail in Appendix C.

- Code C - Dedicated fuel oil user during 1977
- Code U - Fuel oil standby; used during 1977
- Code T - Fuel oil standby; used for testing only during 1977
- Code O - Nonfuel oil user
- Code S - Fuel oil standby; not used during 1977
- Code N - Nonrespondent
- Code R - Removed from service or unable to locate
- Code D - Deleted from source list
- Code K - Source fired crude oil and/or kerosene exclusively during 1977

Of particular importance to the survey results was the impact of an ongoing ARB boiler survey. Due to confidentiality problems over access to the SCAQMD files, questionnaires were mailed to counties in the South Coast Air Basin during the latter part of 1980. Unaware to PES, the regulatory group of ARB mailed out very similar boiler questionnaires to the SCAB at about the same period. The questionnaires were so similar that in recontacting sources in the SCAB many of them stated that they had received two questionnaires but only sent one back. In fact, PES received a few ARB questionnaires in PES return envelopes. This partially explains the initially low response rate for the SCAB. It should be noted that because of this problem, and assuming that the survey questionnaire response rate would have been similar to the remainder of the state, PES had to spend an inordinate amount of time

Table 4-17. SURVEY RESPONSE DISTRIBUTION AND FUEL OIL ESTIMATES BY COUNTY

COUNTY	FUEL CONSUMPTION[a]	RESPONSE CODE									TOTAL
		C	U	T	O	S	N	R	D	K	
Alameda											
EIS	5,590	5	6	0	0	3	0	0	0	0	
Non-EIS	2,500	1	1	5	9	8	7	0	0	0	
Total	8,090	6	7	5	9	11	7	0	0	0	45
Alpine											
EIS	0	0	0	0	0	0	0	0	0	0	
Non-EIS	0	0	0	0	0	0	2	0	0	0	
Total	0	0	0	0	0	0	2	0	0	0	2
Amador											
EIS	0	0	0	0	0	0	0	0	0	0	
Non-EIS	0	0	0	0	0	1	0	0	0	0	
Total	0	0	0	0	0	1	0	0	0	0	1
Butte											
EIS	1,840	1	3	0	0	1	0	0	0	0	
Non-EIS	0	0	0	0	1	0	0	0	0	0	
Total	1,840	1	3	0	1	1	0	0	0	0	6
Calaveras											
EIS	106	1	2	0	0	0	0	0	0	0	
Non-EIS	36	1	2	0	0	0	2	1	0	0	
Total	142	2	4	0	0	0	2	1	0	0	9

COUNTY	FUEL CONSUMPTION[a]	RESPONSE CODE									TOTAL
		C	U	T	O	S	N	R	D	K	
Colusa											
EIS	0	0	0	0	0	2	0	0	0	0	
Non-EIS	0	0	0	0	0	2	0	0	0	0	
Total	0	0	0	0	0	4	0	0	0	0	4
Contra Costa											
EIS	41,100	7	4	0	1	3	0	1	0	1	
Non-EIS	487	1	2	0	2	9	7	0	0	0	
Total	41,590	8	6	0	3	12	7	1	0	1	38
Del Norte											
EIS	410	1	1	0	0	0	0	0	0	0	
Non-EIS	81	1	0	0	0	0	4	0	0	0	
Total	491	2	1	0	0	0	4	0	0	0	7
El Dorado											
EIS	200	0	2	0	0	0	0	0	0	0	
Non-EIS	22	0	2	0	5	1	9	0	0	0	
Total	222	0	4	0	5	1	9	0	0	0	19
Fresno											
EIS	10,290	5	1	0	0	1	0	0	0	1	
Non-EIS	1,220	3	7	2	15	46	61	1	1	1	
Total	11,510	8	8	2	15	47	61	1	1	2	145

COUNTY	FUEL CONSUMPTION[a]	RESPONSE CODE									TOTAL
		C	U	T	O	S	N	R	D	K	
Glenn											
EIS	1,430	0	1	0	0	1	0	0	0	0	
Non-EIS	0	0	0	0	1	0	1	0	0	0	
Total	1,430	0	1	0	1	1	1	0	0	0	4
Humboldt											
EIS	10,900	4	0	0	0	0	0	0	0	0	
Non-EIS	0	0	0	0	1	1	3	0	0	0	
Total	10,900	4	0	0	1	1	3	0	0	0	9
Imperial											
EIS	22,780	0	4	0	0	2	0	0	0	0	
Non-EIS	0	1	0	0	0	1	2	0	0	0	
Total	22,780	1	4	0	0	3	2	0	0	0	10
Inyo											
EIS	3,570	2	0	0	0	0	0	0	0	0	
Non-EIS	226	4	4	0	0	2	6	0	0	0	
Total	3,796	6	4	0	0	2	6	0	0	0	18
Kern											
EIS	82,600	16	4	0	11	0	2	0	0	46	
Non-EIS	1,300	2	3	0	18	1	16	2	0	3	
Total	83,900	18	7	0	29	1	18	2	0	49	124

COUNTY	FUEL CONSUMPTION[a]	RESPONSE CODE									TOTAL
		C	U	T	O	S	N	R	D	K	
Kings											
EIS	2,790	2	1	0	0	1	0	0	0	0	
Non-EIS	132	1	3	0	0	8	1	0	0	0	
Total	2,922	3	4	0	0	9	1	0	0	0	17
Lake											
EIS	0	0	0	0	0	0	0	0	0	0	
Non-EIS	119	3	1	0	0	0	2	0	0	0	
Total	119	3	1	0	0	0	2	0	0	0	6
Lassen											
EIS	1,400	3	0	0	0	0	0	0	0	0	
Non-EIS	316	2	0	0	0	0	8	0	1	0	
Total	1,716	5	0	0	0	0	8	0	1	0	14
Los Angeles											
EIS	63,860	8	100	3	6	82	17	3	0	0	
Non-EIS	9,545	13	54	5	49	193	265	17	9	0	
Total	73,400	21	154	8	55	275	282	20	9	0	824
Madera											
EIS	402	1	1	0	0	0	1	0	0	0	
Non-EIS	796	1	2	0	1	6	6	0	1	0	
Total	1,198	2	3	0	1	6	7	0	1	0	20

COUNTY	FUEL CONSUMPTION[a]	RESPONSE CODE									TOTAL
		C	U	T	O	S	N	R	D	K	
Marin											
EIS	0	0	0	0	0	0	0	0	0	0	
Non-EIS	0	0	0	0	0	0	2	0	0	0	
Total	0	0	0	0	0	0	2	0	0	0	2
Mariposa											
EIS	0	0	0	0	0	0	0	0	0	0	
Non-EIS	0	0	0	0	0	0	5	0	0	0	
Total	0	0	0	0	0	0	5	0	0	0	5
Mendocino											
EIS	9,166	3	1	0	0	0	0	0	0	0	
Non-EIS	172	0	1	0	2	0	2	0	0	0	
Total	9,338	3	2	0	2	0	2	0	0	0	9
Merced											
EIS	0	0	0	0	0	0	0	0	0	0	
Non-EIS	1,924	0	3	0	7	0	7	0	0	0	
Total	1,924	0	3	0	7	0	7	0	0	0	17
Modoc											
EIS	0	0	0	0	0	0	0	0	0	0	
Non-EIS	52	1	1	0	2	2	3	0	1	0	
Total	52	1	1	0	2	2	3	0	1	0	10

COUNTY	FUEL CONSUMPTION[a]	RESPONSE CODE C	U	T	O	S	N	R	D	K	TOTAL
Mono											
EIS	0	0	0	0	0	1	0	0	0	0	
Non-EIS	0	0	0	0	4	0	1	0	0	0	
Total	0	0	0	0	4	1	1	0	0	0	6
Monterey											
EIS	15,503	3	1	0	0	1	0	0	0	1	
Non-EIS	430	0	4	4	3	4	7	0	1	1	
Total	15,930	3	5	4	3	5	7	0	1	2	30
Napa											
EIS	57	0	0	0	0	0	0	0	0	0	
Non-EIS	0	0	1	0	1	1	0	0	0	0	
Total	57	0	1	0	1	1	0	0	0	0	3
Nevada											
EIS	330	1	0	0	1	0	1	0	0	0	
Non-EIS	73	0	1	1	1	0	4	0	0	0	
Total	403	1	1	1	2	0	5	0	0	0	10
Orange											
EIS	5,480	4	26	2	2	32	2	2	0	0	
Non-EIS	490	6	8	1	10	24	16	0	1	0	
Total	5,970	10	34	3	12	56	18	2	1	0	136

COUNTY	FUEL CONSUMPTION[a]	RESPONSE CODE									TOTAL
		C	U	T	O	S	N	R	D	K	
Placer											
EIS	0	0	0	0	0	0	0	0	0	0	
Non-EIS	106	1	1	0	7	0	8	0	1	0	
Total	106	1	1	0	7	0	8	0	1	0	18
Plumas											
EIS	903	2	1	0	0	0	0	0	0	0	
Non-EIS	20	0	1	0	3	1	5	0	4	0	
Total	923	2	2	0	3	1	5	0	4	0	17
Riverside											
EIS	10,340	4	12	0	1	10	0	1	0	0	
Non-EIS	76	1	3	0	4	9	4	0	1	0	
Total	10,420	5	15	0	5	19	4	1	1	0	50
Sacramento											
EIS	3,560	3	2	0	0	0	1	0	0	0	
Non-EIS	1,240	1	5	0	3	3	3	0	0	0	
Total	4,800	4	7	0	3	3	4	0	0	0	21
San Benito											
EIS	211	0	1	0	0	1	0	0	0	0	
Non-EIS	22	0	1	0	0	1	0	0	0	0	
Total	233	0	2	0	0	2	0	0	0	0	4

COUNTY	FUEL CONSUMPTION[a]	RESPONSE CODE									TOTAL
		C	U	T	O	S	N	R	D	K	
San Bernardino											
EIS	82,300	7	26	1	0	20	0	3	0	0	
Non-EIS	167	1	3	0	6	11	20	0	0	0	
Total	82,470	8	29	1	6	31	20	3	0	0	98
San Diego											
EIS	6,630	0	5	0	1	1	1	1	0	1	
Non-EIS	503	3	11	4	12	7	20	0	2	0	
Total	7,133	3	16	4	13	8	21	1	2	1	69
San Francisco											
EIS	200	1	0	0	0	0	0	0	0	0	
Non-EIS	3	0	1	1	9	6	14	0	0	0	
Total	203	1	1	1	9	6	14	0	0	0	32
San Joaquin											
EIS	16,100	5	17	1	0	30	0	1	0	0	
Non-EIS	78	0	1	0	1	2	1	0	0	1	
Total	16,180	5	18	1	1	32	1	1	1	1	61
San Luis Obispo											
EIS	132	4	1	0	0	0	0	0	0	0	
Non-EIS	1,123	4	11	0	1	3	1	0	0	0	
Total	1,255	8	12	0	1	3	1	0	0	0	25

COUNTY	FUEL CONSUMPTION[a]	RESPONSE CODE									TOTAL
		C	U	T	O	S	N	R	D	K	
San Mateo											
EIS	353	1	1	0	0	0	0	0	0	0	
Non-EIS	2	0	0	1	7	3	0	0	1	0	
Total	355	1	1	1	7	3	0	0	1	0	14
Santa Barbara											
EIS	5,317	2	3	0	3	3	0	0	0	0	
Non-EIS	9	0	1	0	0	0	3	0	0	0	
Total	5,326	2	4	0	3	3	3	0	0	0	15
Santa Clara											
EIS	116	3	1	0	2	0	1	0	0	0	
Non-EIS	256	3	1	0	2	2	10	0	0	0	
Total	372	6	2	0	4	2	11	0	0	0	25
Santa Cruz											
EIS	11,930	3	0	0	0	1	0	0	0	0	
Non-EIS	9	0	0	1	1	10	4	0	0	0	
Total	11,940	3	0	1	1	11	4	0	0	0	20
Shasta											
EIS	1,200	1	0	0	1	1	1	1	0	0	
Non-EIS	0	0	0	0	1	0	4	0	0	0	
Total	1,200	1	0	0	2	1	5	1	0	0	10

COUNTY	FUEL CONSUMPTION[a]	RESPONSE CODE									TOTAL
		C	U	T	O	S	N	R	D	K	
Sierra											
EIS	0	0	0	0	0	0	0	0	0	0	
Non-EIS	0	0	0	0	0	1	1	0	0	0	
Total	0	0	0	0	0	1	1	0	0	0	2
Siskiyou											
EIS	0	0	0	0	0	0	0	0	0	0	
Non-EIS	599	5	4	0	0	4	16	0	0	0	
Total	599	5	4	0	0	4	16	0	0	0	29
Solano											
EIS	607	2	1	0	0	2	0	0	0	0	
Non-EIS	1,600	1	0	0	1	0	5	0	0	0	
Total	2,207	3	1	0	1	2	5	0	0	0	12
Sonoma											
EIS	150	1	0	0	0	0	0	0	0	0	
Non-EIS	953	1	2	2	1	2	8	0	0	0	
Total	1,103	2	2	2	1	2	8	0	0	0	17
Stanislaus											
EIS	7,150	3	6	0	1	7	0	0	0	1	
Non-EIS	568	3	6	0	3	12	3	0	0	0	
Total	7,718	6	12	0	4	19	3	0	0	1	45

COUNTY	FUEL CONSUMPTION[a]	RESPONSE CODE									TOTAL
		C	U	T	O	S	N	R	D	K	
Sutter											
EIS	89	0	4	0	0	0	0	0	0	0	
Non-EIS	0	0	0	0	2	0	4	0	0	0	
Total	89	0	4	0	2	0	4	0	0	0	10
Tehama											
EIS	0	0	0	0	1	0	0	0	0	0	
Non-EIS	0	0	0	0	0	0	0	0	0	0	
Total	0	0	0	0	1	0	0	0	0	0	1
Trinity											
EIS	0	0	0	0	0	0	0	0	0	0	
Non-EIS	14	0	1	0	0	0	2	0	0	0	
Total	14	0	1	0	0	0	2	0	0	0	3
Tulare											
EIS	349	1	1	0	0	0	0	0	0	0	
Non-EIS	2,640	0	5	0	2	4	4	0	1	0	
Total	2,989	1	6	0	2	4	4	0	1	0	18
Tuolumne											
EIS	2,140	1	2	0	0	0	0	0	0	0	
Non-EIS	16	0	1	0	10	0	14	0	3	0	
Total	2,156	1	3	0	10	0	14	0	3	0	31

COUNTY	FUEL CONSUMPTION[a]	RESPONSE CODE									TOTAL
		C	U	T	O	S	N	R	D	K	
Ventura											
EIS	3,520	1	14	1	1	7	4	0	0	1	
Non-EIS	654	1	4	0	0	4	2	0	0	0	
Total	4,174	2	18	1	1	11	6	0	0	1	40
Yolo											
EIS	1,390	0	2	0	0	4	3	0	0	0	
Non-EIS	291	0	1	0	0	0	0	0	0	0	
Total	1,681	0	3	0	0	4	3	0	0	0	10
Yuba											
EIS	576	2	0	0	2	0	1	0	0	0	
Non-EIS	0	0	0	0	6	0	3	0	0	0	
Total	576	2	0	0	8	0	4	0	0	0	14
State totals	466,000	180	422	36	248	612	643	34	29	57	2,261

[a] Expressed in thousands of gallons

recontacting nonresponding EIS sources to rectify the situation. Due to time constraints, nonresponding non-EIS sources did not undergo this rigorous recontacting procedure.

Another significant problem occurred, this time with the Kern County portion of the survey. From the Kern County APCD visit and from reviewing the results of the agency's 1977 survey of the county's extensive petroleum related industry, it was noted that a majority of these sources burn fuel oil. As such, these sources, many of whom are on the EIS file, were added to the survey file. After reviewing some of the returned questionnaires and subsequently comparing these data to the APCD survey data, a major discrepancy was discovered. After a number of telephone calls to these sources as well as a few of the nonrespondents, it was discovered that many of the sources misinterpreted the APCD questionnaire. These sources mistakenly reported the amount they produced as the amount they fired during the year. This was due in part to the design of the questionnaire being somewhat confusing. As such, the data collected during the APCD visit could not be used to fill the "gap" generated by the nonrespondents. One further point: it is believed that since the APCD surveys these sources annually they were understandably reluctant to respond to this survey.

Nevertheless, from questionnaires received and from contact with many of the sources, it is presumed although not totally verified, that many of the petroleum related facilities in Kern County fire crude exclusively. Therefore, since crude oil was not contained in the fuel oil definition that this study was operated under, these were not considered users.

Finally, from contact with Kern County APCD, PES learned that the agency has resolved the ambiguities in their questionnaire.

4.4.6 SURVEY RESULTS

A computer program was constructed to sort, calculate and compile the data contained in the various DHS files described in Appendix C. Although there is a wide spectrum of possible output formats, the following adequately illustrates the results of this portion of the study. It should be emphasized that the DHS data files were constructed to allow flexibility in output formats. Thus, the ARB will be able to reformat the data at some later date to the requirements of future needs.

The fuel oil totals were summarized earlier in Table 4-17. These totals are reported by county and by EIS and non-EIS sources. This table allows for easy examination of the relationships between the totals and the corresponding response codes. As indicated, total fuel oil consumption in the state, as surveyed, is estimated to be 466 million gallons during 1977. Further, the counties of Kern, Los Angeles, Riverside and San Bernardino consumed approximately 53 percent of the total.

Table 4-18 displays the state total by fuel oil type while Table 4-19 indicates their physical characteristics. For the most part, sources were not able to supply detailed information concerning the fuel oil they use. Consequently, some of these data have to be used with caution, especially the data that are based on a small response. For reference, the reported total heat content values are compared by cross referencing the reported degree API with published heat content data.

Table 4-18. FUEL OIL CONSUMPTION RATES BY TYPE

FUEL OIL TYPE	FUEL CONSUMPTION ($x\ 10^6$ gal)	PERCENT OF TOTAL
No. 1	2.41	0.5
No. 2	105.	23.5
No. 4	6.2	1.5
No. 5	42.7	9.2
No. 6	309.	66.0
TOTAL	466.	100

For the most part, sources tended to provide degree API, sulfur content, and heat content. Relatively few reported ash content, nitrogen, and metal content. In an effort to further qualify these data, numerous fuel oil suppliers and a number of refineries were queried. A list of fuel oil suppliers as developed from questionnaire responses is presented in Appendix C. In general, the contacts indicated that the refined fuel oils are guaranteed within the ASTM requirements and that the individual characteristics can vary within those ranges (refer to Table 3-1).

Of particular interest is the relationship between major SIC groups (two digit) and the total fuel consumption. Table 4-20 illustrates this distribution.

Finally, Figure 4-5 graphically displays the monthly temporal pattern for the total fuel oil consumed by these sectors.

Table 4-19. AVERAGE FUEL OIL CHARACTERISTICS DETERMINED FROM SURVEY

FUEL OIL TYPE	°API	ASH CONTENT (% by wt.)	SULFUR CONTENT (% by wt.)	NITROGEN CONTENT (% by wt.)	METAL CONTENT ppm	TOTAL HEAT CONTENT ($\times 10^3$ Btu/gal)	
						Survey	Ref. 24[c]
No. 1	41.4[a]	0.013	0.16	0.025[a]	10[a]	1,317	1,358
No. 2	33.3[b]	0.016	0.35[b]	0.016	49	1,392[b]	1,398
No. 4	28.0[a]	0.068	0.55	0.030[a]		1,455	1,431
No. 5	17.1	0.21	0.68	0.035	235[a]	1,475	1,500
No. 6	15.4[b]	0.22[b]	0.72[b]	0.034	152	1,488[b]	1,512

[a]Less than 10 sources reporting.

[b]More than 50 sources reporting.

[c]Extracted from Reference 24 based on average degree API from survey.

Table 4-20. FUEL OIL CONSUMPTION IN THE INDUSTRIAL, COMMERCIAL AND INSTITUTIONAL SECTORS BY MAJOR SIC GROUP, 1977

MAJOR SIC GROUP	PRINCIPAL BUSINESS ACTIVITY	PERCENT OF SURVEY TOTAL
32	Stone clay and glass products	19.0
29	Petroleum refining and related industries	16.6
13	Oil and gas extraction	17.7
39	Miscellaneous manufacturing industries	1.2
49	Electric, gas and sanitary services	7.3
20	Food and kindred products	7.4
26	Paper and allied products	7.2
28	Chemicals and allied products	6.4
80	Health services	1.4
24	Lumber and wood products, except furniture	2.6
97	National security and international affairs	2.8
37	Transportation services	1.6
14	Mining and quarrying of nonmetallic minerals, except fuels	2.9
82	Educational services	1.3
33	Primary metals industry	1.6
	Others	3.0

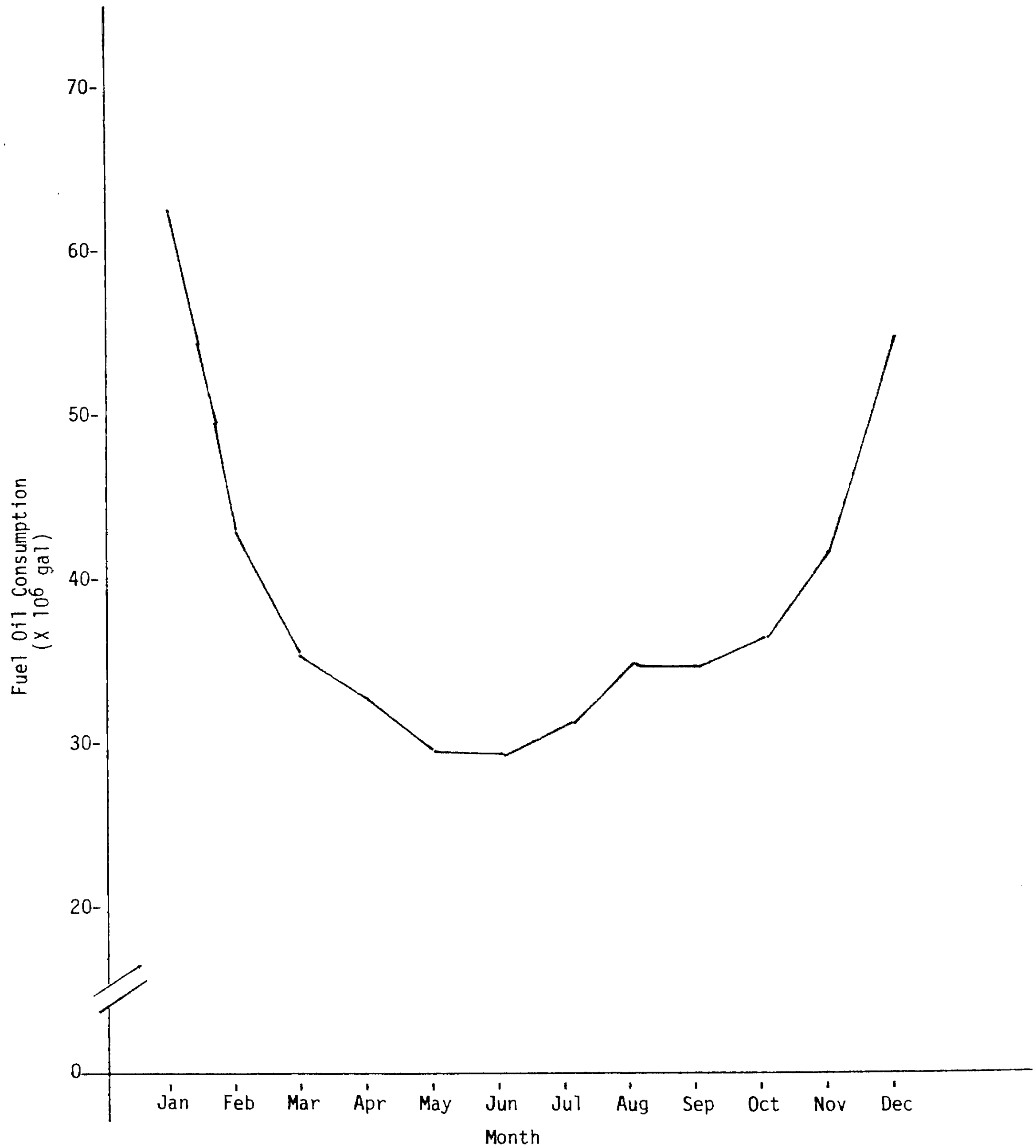

Figure 4-5. Consumption Pattern for the Industrial, Commercial and Institutional Sectors at the State Level, 1977

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